HEAVENLY VALLEY RESORT CANYON TEST PLOTS REPORT

May 2008

INTRODUCTION

This report describes monitoring data and results from Heavenly Valley Ski Resort long-term soil research test plots (Heavenly test plots) and a native reference plot. The Heavenly test plots are located at the Heavenly Valley Mountain Resort, which spans the California and Nevada border area near the southeast corner of Lake Tahoe (Figure 1). A total of 26 plots were constructed in 2003, including 18 treatment plots, six control plots, and two untreated plots. The plots were installed at the bottom of Betty's Bowl ski run, near the Canyon chairlift (Figure 2). The native reference area is adjacent to Betty's Bowl ski run in a forested area. The ski run had been treated with rough grading in the past and tree stumps and rocks were removed. The Heavenly test plots were constructed on an eroding granitic parent material slope, which is a common situation throughout the Lake Tahoe area, whether at ski resorts or on roadsides. The monitoring results from the Heavenly test plots will have applications for land managers throughout the Lake Tahoe area.

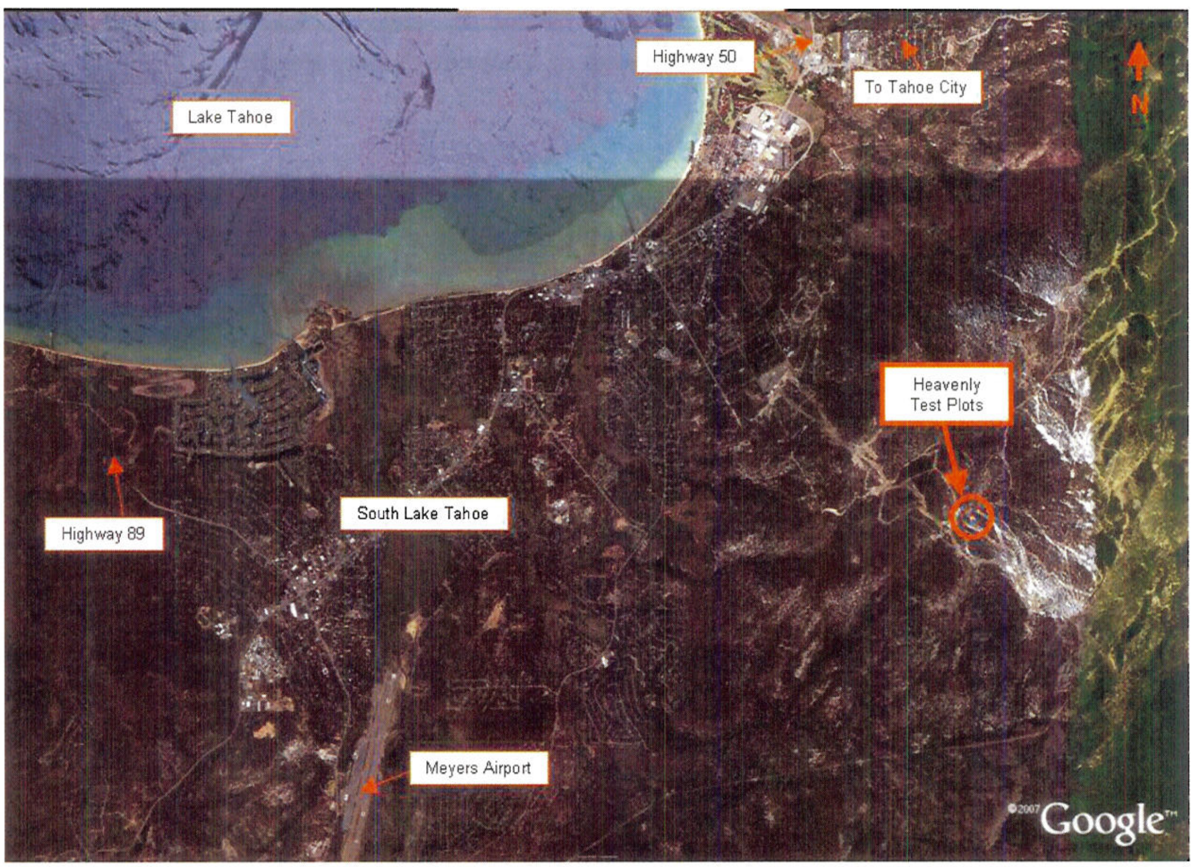

Figure 1. Test and reference plots site location near the southeast side of Lake Tahoe.

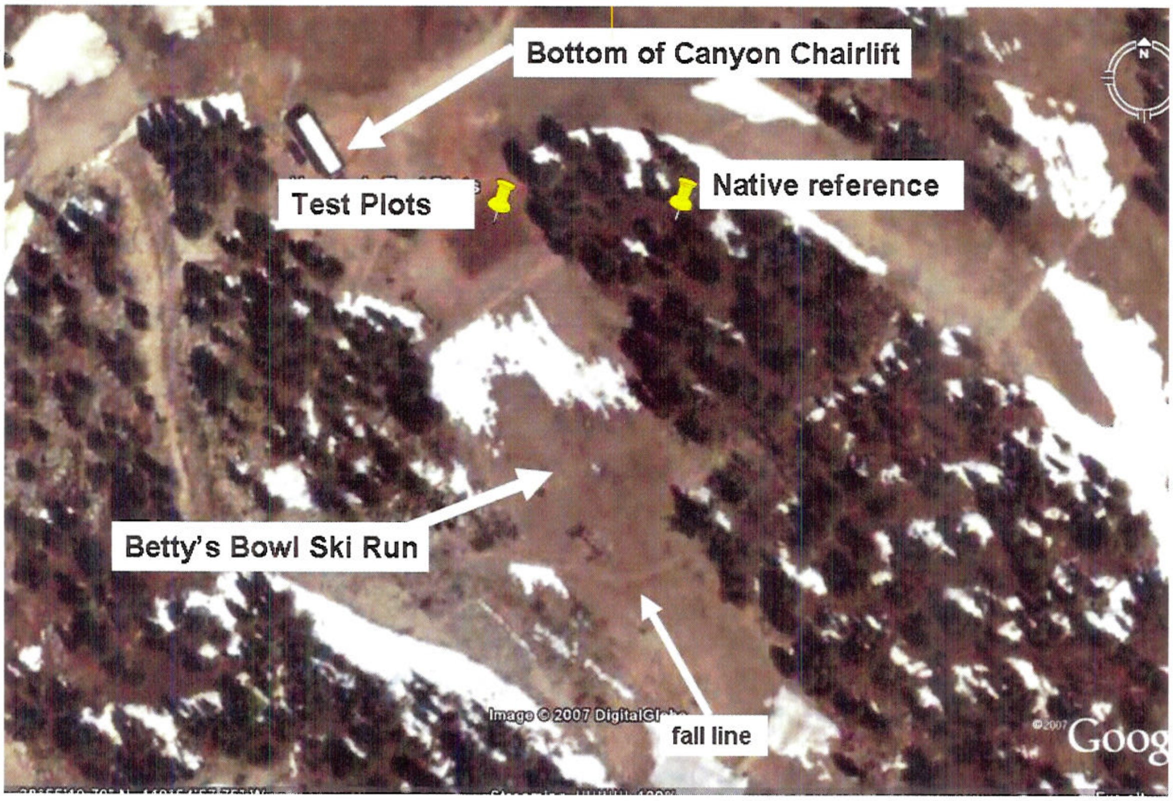

Figure 2. Test plot and reference site location at Heavenly Valley Resort.

PURPOSE

The Heavenly test plots were installed to create long-term soil research plots on granitic parent material soils. Many of the roadside cut slopes throughout the Lake Tahoe basin are in soils of granitic parent material, so the information collected from these plots can be applied to Caltrans roadside restoration throughout the Lake Tahoe Basin area. The specific objectives were to investigate the effects of eight treatment types on soil density, soil nutrient status, and infiltration. The eight treatment types are listed in Table 1 and the layout of the plots is presented in Figure 3. The treatment variables were: tilling versus no tilling, Biosol fertilizer rate, and amendment type (compost, coarse overs, or woodchips). All treatment areas received a native grass seed mix. Initially, these plots were created for soil research; therefore, plant cover was only estimated ocularly in 2006. However, after observing differences in plant cover and species composition by treatment in 2006, more objective and rigorous cover point monitoring was used in 2007 to obtain a statistically defensible measure of plant cover by species.

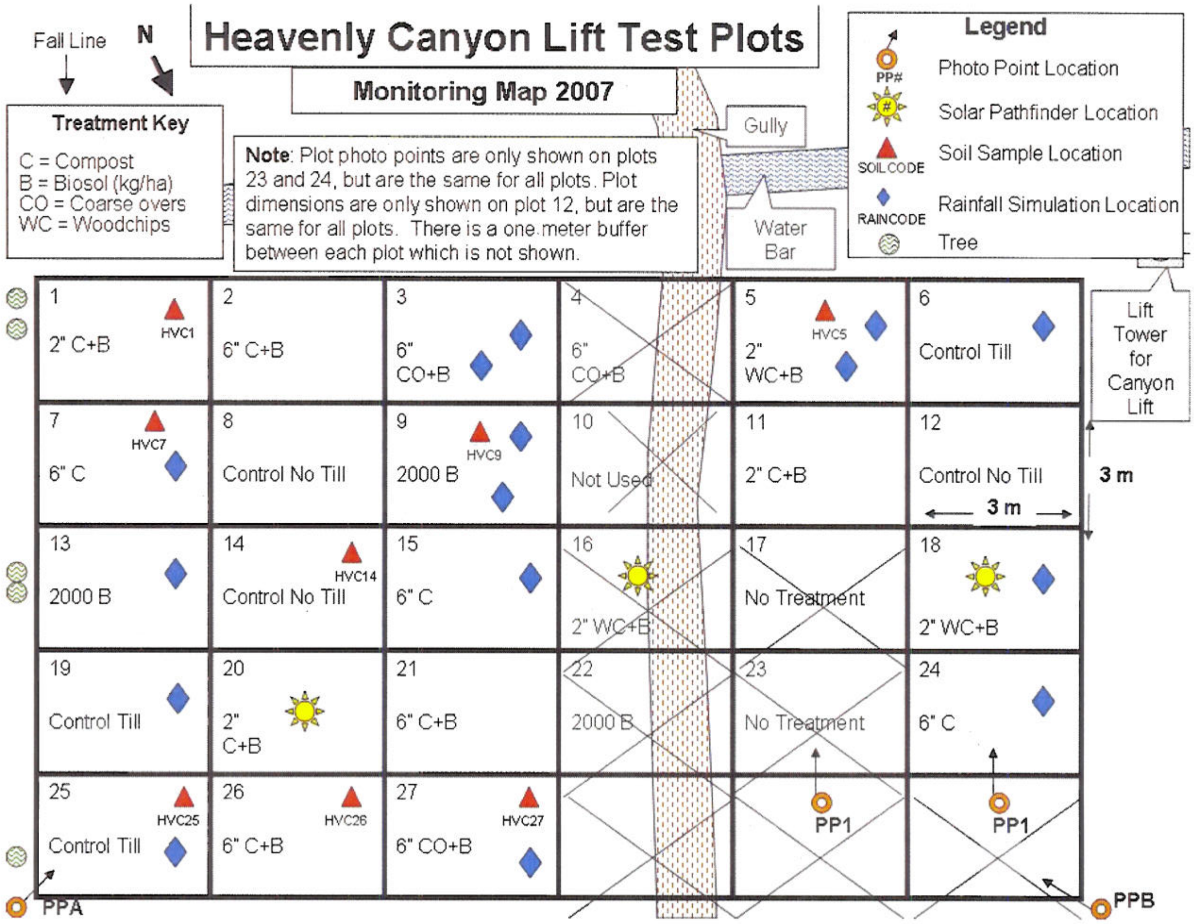

Figure 3. Heavenly Test Plot Layout with 2007 sampling locations marked. Plots 4, 10, 16, and 22 have a large gully running through the plots that originates upslope of the test plots. In 2007, plots in this gully were not sampled due to excessive soil disturbance.

SITE DESCRIPTION

The test plots are located at the bottom of Betty's Bowl, a north facing ski slope at Heavenly Ski Resort. The slope angle at the test plots is approximately 16 degrees. Soils in the test area are derived from granitic parent material. Soil particle size analysis classified the soil within the test plot area as a sandy loam to sand with greater than 86% sand, 6% to 8% silt and 5% clay. Local native vegetation consists of a higher elevation mixed conifer forest with Western white pine (*Pinus monticola*), red fir (*Abies magnifica*) and lodgepole (*Pinus contorta*), as the dominant overstory species. The understory vegetation consists of forbs and grasses. Several of the species observed in the native plot were: pioneer rockcress (*Arabis platysperma*), spike tritesum (*Tritesum spicatum*) and Ross's sedge (*Carex rosii*). The site elevation is 8,562 feet (2,610 meters) above mean sea level (AMSL). The soils in the test plot area have on average 17 percent coarse material (greater than ½ inch diameter). Soil particle size analysis, conducted in 2007 on the material finer than ½ inch, showed that soils at both the treated and untreated plots were greater than 85% sand and less than 15%

silt and clay. Prior to treatment, the area exhibited rills and sheet erosion (Figure 4).

METHODS & MATERIALS

Treatment Overview

Twenty-seven 10 feet by 10 feet (3 meters x 3 meters) plots with a 3.3 feet (1 meter) buffer on all sides were placed in a grid that was nine plots wide by three plots high (Figure 2). Eighteen of the plots were considered "full treatment" and received tilling and amendments, which are described below (Table 1). Three plots received deep tilling, but not with amendments. These plots did receive seed and mulch. The last three treatment plots received seed and surface mulch, but no deep tilling of amendments. The three remaining plots were not treated, making a total of 24 plots that received treatments (Figure 2). Treatments were randomly located within the site area. A gully formed upslope of the test plots prior to the 2006 sampling season and ran directly down slope through plots 4, 10, 16, and 22. In 2007, this gully has affected the ground and plant cover on these plots (Figure 4). These plots were sampled in 2006, but the disturbance had increased by the 2007 season, and sampling was not conducted at these plots at that time.

Table 1. Treatment descriptions and abbreviations used throughout the report.

Plot numbers	Treatment Descriptions	Abbreviation
9, 13, 22	2,000 kg /ha Biosol, seed, and mulch	Biosol
1, 11, 20	2 inches Compost and Biosol, seed, and mulch	2" Compost + Biosol
5,16,18	2 inches Woodchips and Biosol, seed, and mulch	2" Woodchips + Biosol
3, 4, 27	6 inches Coarse overs and Biosol, seed, and mulch	6" Coarse overs +Biosol
7, 15, 24	6 inches Compost, seed, and mulch	6" Compost
2, 21, 26	6 inches Compost and Biosol, seed and mulch	6" Compost +Biosol
6, 19, 25	Tilling, seed, and mulch	Control Till
8, 12, 14	No tilling, seed, and mulch	Control No Till
10, 17, 23	No Treatment/Not Used	No Treatment

Test Plot Treatments

First, amendments were spread over the test plots. Three different types of amendments, applied at two different rates were used on this project. The three types of amendments were compost, wood chips, and coarse overs. The compost and coarse overs were obtained from Full Circle Compost. The compost was the Integrated Tahoe Blend 100% a screened compost consisting of humus fines less than 3/8 inch (0.95 cm) in diameter. Coarse overs are the woody material remaining after compost is screened, ranging in diameter from 3/8 of an inch (0.95 cm) to 3 inches (7.6 cm). The woodchips were supplied by Heavenly Valley Resort. Two inches (5 cm) of woodchips were applied at a nitrogen (N) equivalent of approximately 104 lbs N/acre (100 kg/ha). Six inches (15.2 cm) of coarse overs were applied at a nitrogen equivalent of approximately 3,500 lbs N/acre (4,000 kg/ha). Compost was applied at two rates; 2 inches, or a nitrogen equivalent of approximately 2,000 lbs N/acre (2,241 kg/ha) and 6 inches, or a nitrogen equivalent of approximately 6,000 lbs N/acre (6,725 kg/ha).

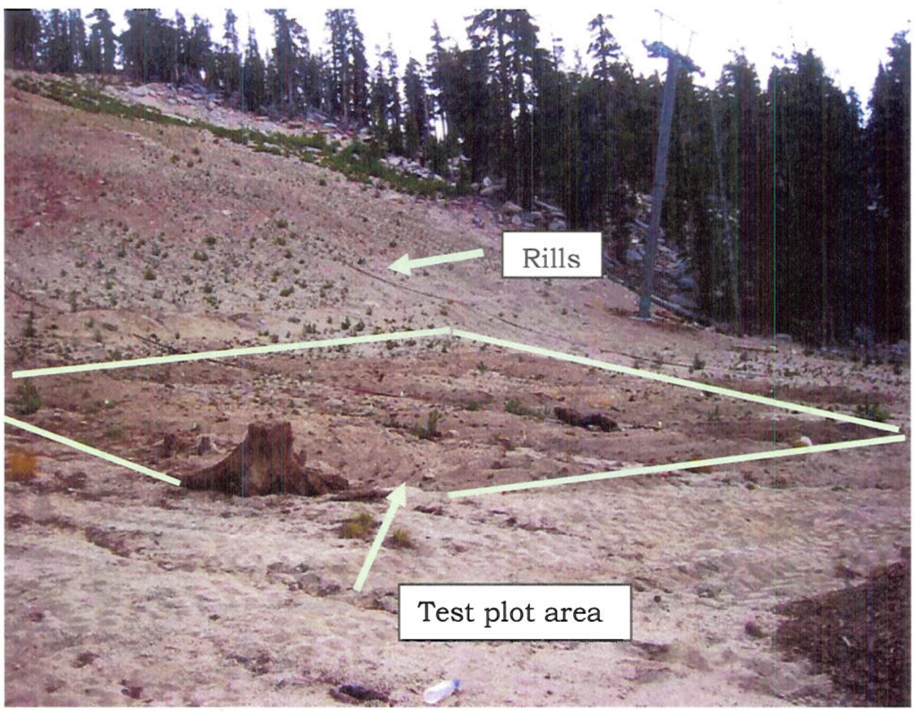

Figure 4. Test plots area following construction. Rills are apparent on the untreated slope above the plots.

After amendments were applied, they were tilled into the soil to a depth of at least 12 inches (30 cm). Tilling of the soil was completed with a Woods backhoe attached to a Kubota 3830 tractor (Figure 5). Each plot was tilled with the tractor positioned on the uphill side of the slope to minimize downslope movement of material. Due to logistical problems and the steepness of the slope, plots 1, 2, and 11 were tilled with a Gradall 43 foot reach forklift.

After the amendments were tilled into the soil, Biosol organic fertilizer, which has a 6-1-3 nitrogen-phosphorous-potassium ratio, was applied on specific plots at a nitrogen equivalent rate of 107 lbs nitrogen/acre (120 kg N/ha) or a bulk rate of 1,780 lbs/acre (2,000 kg/ha). The Biosol was applied by hand after each plot was tilled, and was then raked into the soil surface to a depth of 1 inch (2.5 cm). The plots were then seeded with native grass seeds (Table 2). The grass seed was applied at an equivalent pure live seed (PLS) rate of 125 lbs/acre (140 kg/ha). The seed was lightly raked into the soil surface to a depth of ¼ inch (0.6 cm) to ensure adequate contact with the soil.

Table 2. Seed mix species composition.

Species	% mix	Portion Viable	Percent Pure Live Seed (PLS)
Mountain brome	29.01	0.87	25.2
Squirreltail	26.56	0.95	25.2
Blue wildrye	24.58	0.77	18.9
Western needlegrass	12.62	0.75	9.5
Total	92.77*		78.9
* The remainder is inert material.			

Approximately 40 square yards (30.5 m^3) of pine needles from Caltrans South Lake Tahoe Snow Storage Yard were used to mulch the test plots (Figure 6). The source of the pine needle mulch was from a Douglas County, Nevada Fire Department collection. The pine needle mulch was applied by hand to the entire treatment area to a thickness of approximately 1.5 inches (3.8 cm). After the pine needle mulch was applied, a paddle agitator-equipped hydroseeder was used to apply tackifier to the entire treatment area. The tank was filled with water, one 50 lb (23 kg) bag of tackifier, and ½ a bale of wood fiber mulch. Two even applications were sprayed on the entire test plot area.

Figure 5. Tilling with a Kubota tractor and Wood's backhoe.

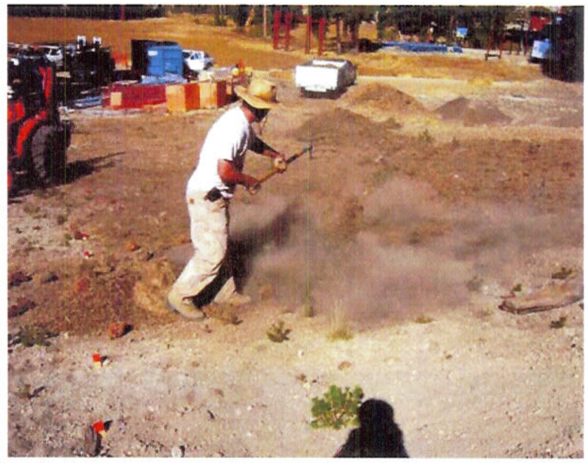

Figure 6. Applying mulch to test plots by hand.

Prior to any treatment in the selected area, ten soil samples were collected from throughout the area to be treated. Soil samples were also taken from three reference sites on the north and east of the ski run. Pre-treatment data collected also includes soil moisture and soil density.

Monitoring

Monitoring at the Heavenly test plots has occurred each year since their construction in 2003. In 2004, rainfall simulation was performed. In 2005, penetrometer and soil moisture was monitored at selected test plots. In 2006, penetrometer and soil moisture was monitored at each numbered test plot as well as at the native area, in a random pattern. Soil samples were also collected at select plots. Rainfall simulation was performed on five of the nine test types in 2006, as well as at the native reference area. In 2007, full suite (penetrometer, soil moisture, cover, shear strength, and soil samples) and rainfall monitoring was conducted at each numbered test plot with the exception of plots 4, 10, 16, and 22. These plots were visibly disturbed by a gully formed from a failure above the test plots. The native reference plot was not monitored in 2007 since it was unlikely that there would be large differences between the 2007 and 2006 sampling data.

Cover

The affect of treatment type on plant cover was not specified as a research question before in depth sampling was performed in 2006. Therefore, until 2007, the more precise and statistically valid cover point method of assessing cover was not conducted at this site. Instead, ground cover by mulch and foliar cover by plants were ocularly estimated at each plot in 2006. Ocular estimates of cover are subjective and vary by examiner. The ocular cover estimates cannot be directly compared with cover point values, but can be used to detect general differences among plots and treatments.

In general, ocular estimates tend to over estimate cover by 10% to 25%. In order to maintain consistency from year to year, ocular estimates were conducted in 2007 along with the more objective statistically defensible cover point monitoring method. Data from ocular estimations and cover point is presented in the results so that ocular estimates for both years may be compared.

These two sets of photos illustrate the difference between plant cover values obtained from ocular estimates and cover point measurements (Figure 7, Figure 8, Figure 9, and Figure 10).

Figure 7. Plot 27, 6 Coarse overs and Biosol in 2006. Ocular estimate of total cover is 52%.

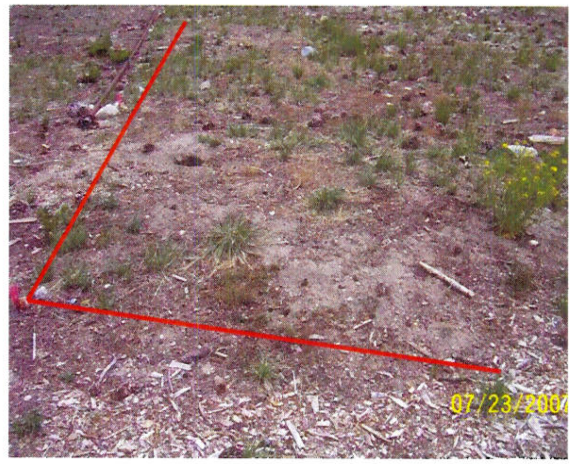

Figure 8. Plot 27, 6 Coarse overs and Biosol in 2007. Ocular estimate of total cover is 35%. Total cover as measured by cover point is 10%.

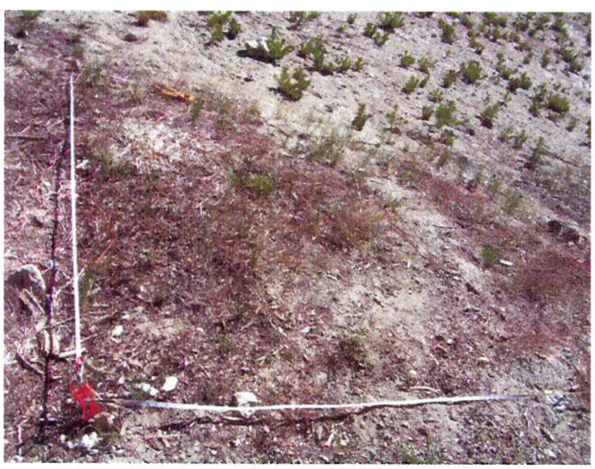

Figure 9. Plot 22, control no till, in 2006. Ocular estimate of total cover is 26.5%.

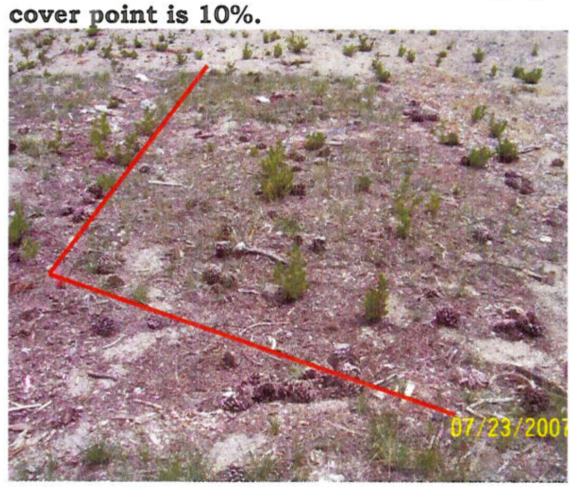

Figure 10. Plot 12, control no till, in 2007. Ocular estimate of total cover is 27%. Total cover as measure by cover point is 12%.

In 2007, cover was measured using the cover point method along randomly located transects.[1] Cover point monitoring is a statistically defensible method of measuring plant and foliar cover (hereafter referred to as either "plant cover" or "foliar plant cover"), plant composition and mulch cover. The cover pointer consists of a metal rod with a laser pointer mounted 3.3 feet (1 meter) high. After the rod was leveled in all directions, the button on the laser pointer was depressed and two cover measurements were recorded (Figure 11 and Figure 12):

- the first hit cover, which represents the first object intercepted starting from a height of 3.3 feet (1 meter) above the ground and
- the ground cover hit.

The first hit cover measures the foliar cover by plants (leaves and stems). It does not measure the part of the plant actually rooted in the ground. The ground cover hit measures whatever is lying on the ground or rooted in the ground (i.e. litter/mulch, bare ground, basal (or rooted) plant cover, rock and woody debris). Total ground cover represents any cover other than bare ground.

Figure 11. Cover pointer in use along transects.

Figure 12. Cover pointer rod with first hit and ground cover hits by the laser pointer. The laser pointer hits are circled in red. The first cover hit is a native grass and the ground cover hit is pine needle mulch.

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[1] Hogan, Michael. Luther Pass Monitoring Report: Plant and Soil Cover Monitoring for Evaluating Sediment Source Control Success in the Lake Tahoe Basin. 2003. South Lake Tahoe, CA, Lahontan Regional Water Quality Control Board.

Plant cover both on the ground and foliar were recorded by species and then organized into cover groups based on four categories: lifeform (herbaceous/woody), perennial/annual, native/alien (2007 only), and seeded/volunteer (2007 only). Perennial herbaceous species includes seeded grasses, native grasses and forbs and any non-native perennial species. Annual herbaceous species included native annuals such as willow herb (*Gayophytum* sp.) and buckwheat (*Eriogonum spergularium*). Few non-native annuals were present at this site. Woody species are any tree and shrub species of interest, whether native or introduced. Each species was then classified based on whether it is native to the Tahoe area, and whether it was seeded during treatment. Data is also presented on the amount of cover by species. Species of interest are species that were seeded and problem species, such as invasive annuals. An ocular estimate of cover at each plot was also recorded in 2006 and 2007 and includes many species not recorded in the cover point sampling (Appendix A).

Soil and Site Physical Conditions

Soil Density

Cone penetrometer measurements were used as an index for soil density. The cone penetrometer, with a ½ inch diameter tip, was pushed straight down into the soil until a maximum pressure of 350 pounds per square inch (psi) (2411 kPa), was reached (Figure 13 and Figure 14). The depth, in inches, at that pressure was recorded as the depth to refusal (DTR). These depth measurements were used as an index for soil density and infiltration capacity. A denser soil is less likely to allow infiltration. Rainfall simulations conducted on roadcuts in Oregon found increased infiltration rates in soils with penetrometer depths to refusal (DTRs) greater than 4 inches (10 cm).[2]

Soil density and soil moisture were measured at all plots in 2006, but with only 10 random measurements per plot. In 2007, soil density, soil moisture and soil strength were measured at all the test plots on transects, with at least 50 measurements per plot. The native site was not monitored in 2007, as it was not expected to change substantially from the previous season. Penetrometer depth to refusal (DTR) was used as an index for soil density.

Soil Moisture

A hydrometer was used to measure volumetric soil moisture content adjacent to the penetrometer readings at a depth of 4.7 inches (12 cm) (Figure 15). In 2005, an average of 25 random penetrometer readings and 10 soil moisture readings

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[2] Grismer, M. Simulated Rainfall Evaluation at Sun River and Mt Bachelor Highways, Oregon. Unpublished.

were taken at test plots for treatments with compost only, Biosol only, woodchips only, coarse overs and Biosol, and the control till plots. An average of 10 random penetrometer readings and 5 soil moisture readings were taken at each test plot in 2006. In 2007, penetrometer and soil moisture measurements were taken along the same randomly located transects as were used for cover point monitoring.

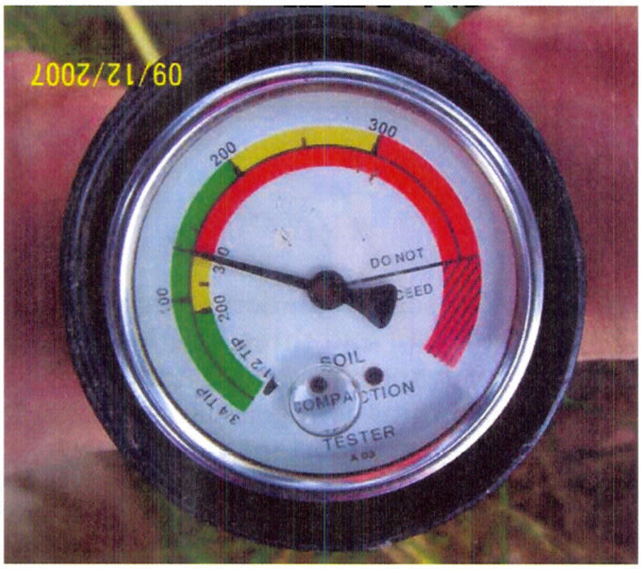

Figure 13. Cone penetrometer dial, showing pressure applied in pounds per square inch.

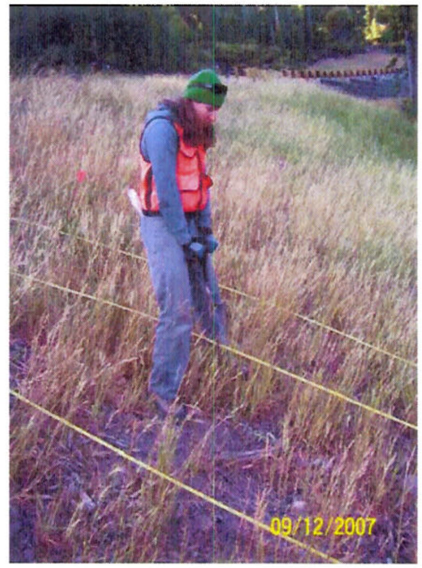

Figure 14. Conducting cone penetrometer readings along transects.

Soil Strength

Soil strength can be an important indication of a soils resistance to mass slope failure under high moisture conditions. Soil strength or a soils resistance to a shear force can be attributed to the internal structure of the soil, to woody material embedded in the soil, and to the presence of plant roots. The density of plant roots has been shown to increase soil strength in laboratory tests.[3]

Soil strength measurements were collected on the same transects as cover, penetrometer, and soil moisture. To measure soil strength, a hand-held shear vane with 1.5 inch (3.8 cm) long blades was pushed into the soil to a depth of 3 inches (7.6 cm) and turned until the soil could no longer resist the force exerted by the blades and the soil structure fractured or deformed (Figure 17). This force was then recorded as the "shear stress" in kilopascals (kPa). Forty kPa was the maximum force the shear vane could measure. Any values above 40

[3] Tengbeh, G.T. 1993. The Effect of Grass Roots on Shear Strength Variations with Moisture Content. *Soil Technology*. Vol. 6. pp. 287-295.

kPa were recorded at 40 kPa and noted as such. This method of determining shear strength has been regularly used in agricultural soils and various laboratory tests.[4]

The shear vane method of testing soil shear strength has not been applied to many forest soils. Large amounts of rocks, coarse organic material (wood, roots and large tub grindings) may affect soil shear strength measurements. Since there was a low proportion of coarse fragments in the Heavenly soils (less than 20%), this should not significantly affect the results. Shear strength was not measured at the control till or control no till plots, since the soil was too dense to insert the vane. The shear vane is an important tool for assessing the in situ strength of the soil, but caution should be used in interpreting the results for forest soils.

Solar Pathfinder

The Solar Pathfinder was used to measure the solar radiation at three locations at the Heavenly test plots (Figure 3 and Figure 16) and three locations at the adjacent native site. Since solar input affects evaporation rates and soil temperature, which may affect time of seed germination, germination rate, rate of plant growth and soil microbial activity, it is an important variable to consider when monitoring plant growth and soil development.

Figure 15. Conducting soil moisture readings along transects.

Figure 16. Solar pathfinder in use.

Figure 17. Soil shear strength tester.

Soil Nutrient Analysis

In 2003, prior to any treatment, ten soil samples were collected from throughout the area to be treated. These soil samples represent baseline soil nutrient levels. In 2006, soil samples were taken from plot 22 (2,000 kg/ha Biosol), plot 25 (Control Till), plot 26 (6 Compost and Biosol), plot 27 (6 Coarse

[4] Tengbeh, G.T. 1993. The Effect of Grass Roots on Shear Strength Variations with Moisture Content. *Soil Technology*. Vol. 6. pp. 287-295.

overs and Biosol), and the native plot. In 2007, soil samples were collected at plots 1 (2 Compost and Biosol), plot 7 (6 Compost), plot 14 (Control no till), plot 16 (2,000 Woodchips and Biosol), Plot 22 (2,000 Biosol), Plot 25 (Control till), Plot 26 (6 Compost and Biosol), and plot 27 (6 Coarse overs and Biosol) (Figure 3). At each soil sample location, three sub-samples were taken of the mineral soil beneath any mulch layer to a depth of 12 inches (30 cm) (Figure 18). These sub-samples were combined, sieved to remove any material larger than 0.08 inches (2mm) in diameter, and sent to A&L Laboratories (Modesto, CA) for the S3C nutrient suite, total Kjeldahl nitrogen (TKN), and organic matter analysis.

Figure 18. Soil sub-sample collection

Rainfall Simulation

Rainfall simulation was conducted in 2004, 2005, 2006, and 2007 on different plots within the treatment area, and in nearby native areas (Table 3). In 2004, three replications were conducted on each plot listed below. Rainfall simulation was not conducted at the native plot in 2004 or 2007. In 2005 and 2006, only one rainfall simulation was conducted on each plot, but three plots of each treatment were used to obtain three replicates of each treatment type (Table 3). In 2007, three replicates were conducted of each treatment type. Since plots 4, 10, 16, and 22 were not monitored; other plots with the same treatments had more than one rainfall frame replication per plot.

Table 3. Rainfall simulation locations 2004 through 2007.

Year	Plots and Treatments for Rainfall Simulation
2004	No till (plot 14) Control till (plot 19) 6" Compost (plot 15) 2" Woodchips + Biosol (plot 16) 6" Coarse overs + Biosol (plot 4).
2005 2006	Control till (plots 6, 25 & 19) Biosol (plots 9, 22 & 13) 6" Compost (plots 7, 15 & 24) 2" Woodchips (plots 5, 16 & 18) 6" Coarse overs + Biosol (plots 3, 4 & 27) Native site (2005 and 2006 only).
2007	Control till (plots 6, 25 & 19) Biosol (plots 9 & 13) 6" Compost (plots 7, 15 & 24) 2" Woodchips (plots 5 & 18) 6" Coarse overs + Biosol (plots 3 & 27)

The rainfall simulator "rains" on a square plot from a height of 3.3 feet (1 meter) (Figure 19 and Figure 20). The rate of rainfall is controlled, and runoff is collected from a trough at the bottom of a 0.6 square meter (6.5 square feet) frame that is pounded into the ground. The volume of water collected is measured; then the volume of infiltration is calculated by subtracting the volume of runoff from the total volume of water applied to the plot. If runoff was not observed during the first 30 minutes, the simulation was stopped. The average steady state infiltration rate was calculated and will hereafter be referred to as "infiltration rate". The collected runoff samples were then analyzed for the average steady state sediment yield (hereafter referred to as "sediment yield").

The cone penetrometer was used to record the DTR surrounding the runoff frames before rainfall simulations. In 2004 and 2005, the DTR was read at 100 psi (689 kPa), which is very low. These values were not used in this report. The 2006 DTR pre-rainfall values that were taken at a maximum pressure of 250 psi (1,724 kPa) and the 2007 DTR values that were taken at 350 psi (2,413 kPa), are presented in this report. Soil moisture was also measured in each runoff frame prior to conducting the rainfall simulations. After rainfall simulation, at least three holes were dug with a trowel to determine the depth to wetting front, which shows how deeply the water infiltrated within the frame. In 2007, at least nine holes were dug to measure the depth to wetting.

Different rainfall rates were applied to different plots depending on their propensity to runoff. The initial rainfall rate applied to the test plots was 2.8 to 3.0 inches/hour (70 to 75 mm/hour). If runoff was not observed, the rainfall rate was increased to 4.7 inches/hour (120 mm/hour) until runoff was observed or all the water was infiltrated. The rainfall rate of 2.8 inches per hour is more than twice the intensity of the 20 year, 1 hour "design storm" for the local area.

Figure 19. Photo of the rainfall simulator and frame.

Figure 20. Photo of the rainfall simulator at the native site, 2006.

Statistical Analysis

An analysis of variance test (ANOVA), which compares average values between two or more different groups, was used to resolve differences between plant and mulch cover values by treatment type, amendment type, and fertilizer (Biosol) application.

If a difference was detected using the ANOVA test, the Mann-Whitney test was used to further investigate differences between two sub-groups or sample sets within the larger group. The Mann-Whitney test is a non-parametric test that can be applied to data sets with non-normal distributions. Non-normal distributions are common within small data sets. At the Heavenly test plots, most of the treatments only have three replications ($n = 3$). Very few statistically signification relationships were found at the Heavenly test plots. Only statistically significant results are presented.

RESULTS/DISCUSSION

Rainfall

Over the four sampling years, different rainfall rates have been applied to the Heavenly test plots and native plots. Some plots that received a lower rainfall rate and infiltrated all the rainfall were not retested at a higher rainfall rate. Thus, their "steady state infiltration rate" appears lower than plots that received a higher rainfall rate. In order to compare infiltration rates or capacity among plots and years the percent of rainfall that infiltrated is presented below (Figure 21). While this presentation also cannot account for the difference in applied rainfall rates, it does clearly show which treatments infiltrated all of the applied rainfall. Sediment was only produced on plots that did not infiltrate 100% of rainfall.

Infiltration and Sediment Yield

High infiltration rates and low sediment yields were observed at all the treatment plots which were similar to or greater than those observed at the native site, (Figure 21 and Figure 22). In 2005, the control till plot produced the highest amount of sediment during rainfall simulation, 70 lbs/acre/inch (78 kg/ha/cm), while the native site produced 45 lbs/acre/in (50 kg/ha/cm) in 2005 and 55 lbs/acre/in (24 kg/ha/in) in 2006 (Figure 21 and Figure 22). In comparison, rainfall simulations that were performed at a disturbed area at the top of the Olympic lift produced an average sediment yield of 1,019 lbs/acre/in (1,136 kg/ha/cm). Other comparable disturbed areas at Heavenly and in the South Lake Tahoe areas had sediment yields that ranged from 113 to 263 lbs/acre/in (125 to 292 kg/h a/cm).

In 2006 and 2007, the control till plots, which had the greatest sediment yield, also infiltrated three times less applied rainfall water than treated plots (Figure 23 and Figure 24).

Tilled plots with coarse organic amendments (woodchips or coarse overs), infiltrated 100% of the applied rainfall and produced no sediment in four years of rainfall simulations (Figure 21 and Figure 22). The Biosol only treatment produced sediment in one sampling year (Figure 22). Other treatments produced sediment, but not at high rates (less than 70 lbs/acre/inch) (Figure 22.

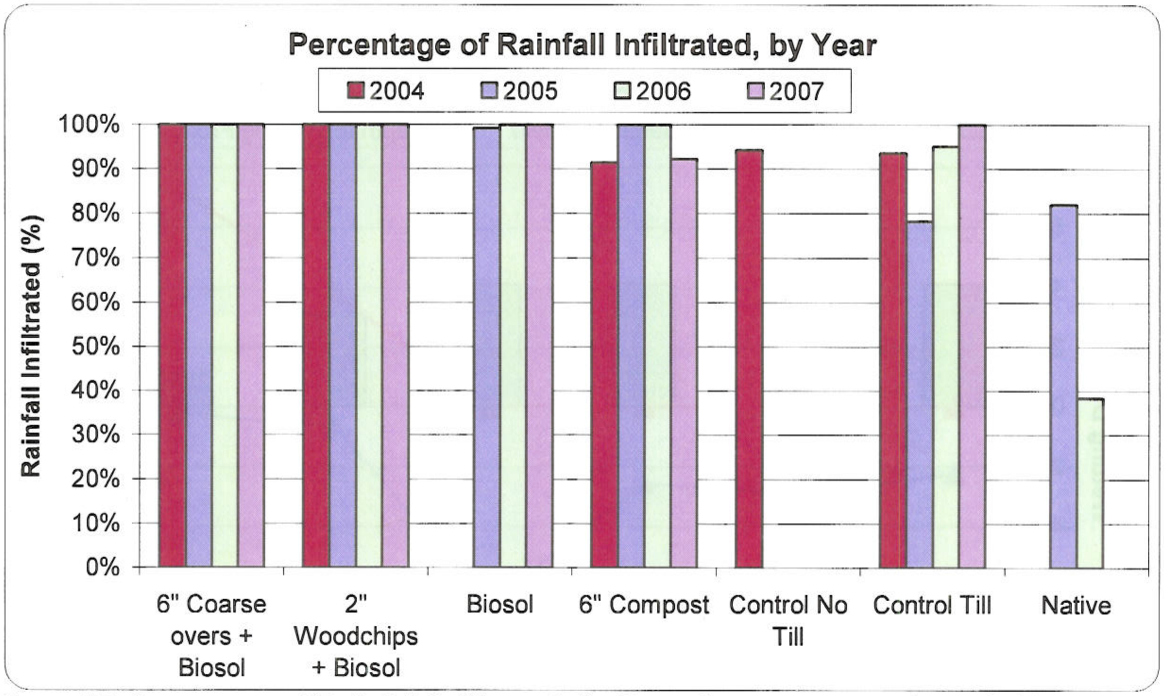

Figure 21. Percentage of Rainfall Infiltrated, by Year. Course overs and woodchips with Biosol infiltrated 100% of rainfall and produced no sediment during the four years of rainfall simulations. The graph is sorted by average rainfall infiltrated over time. Rainfall simulation was not conducted at all sites in all years.

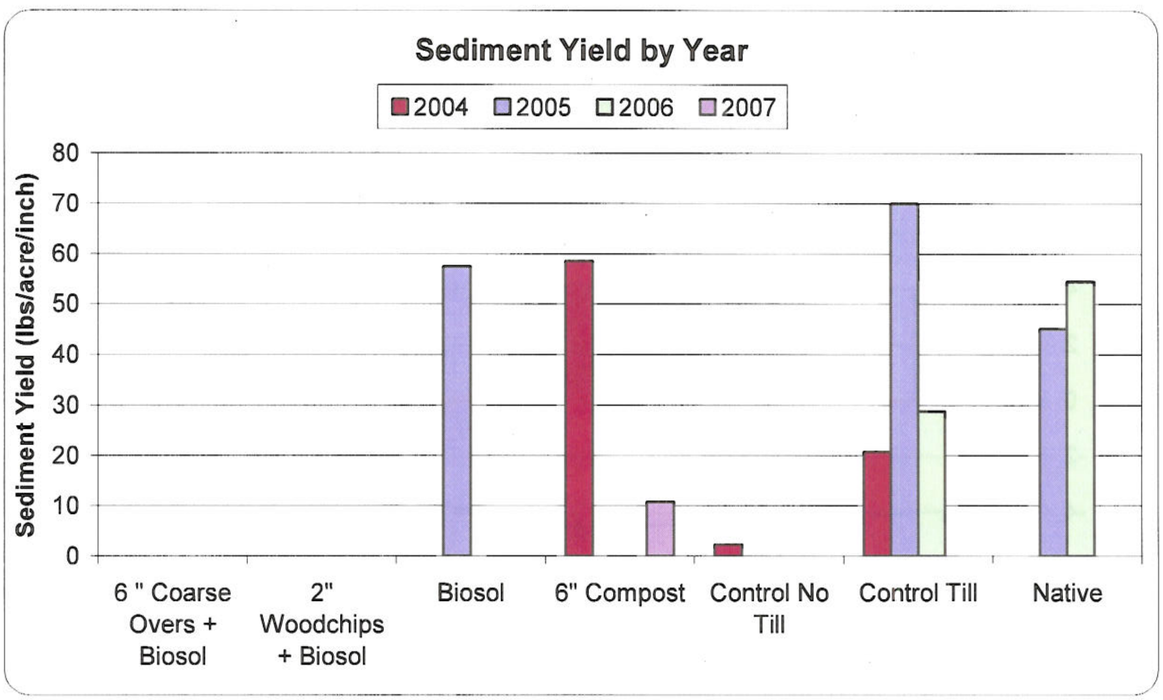

Figure 22. Sediment Yield, by Year. The plots treated with coarse overs and woodchips produced no sediment over the four years of monitoring. If a bar is not presented either no sediment was produced or rainfall simulation was not conducted at that plot. Figure 21 shows which plots received rainfall in a given year.

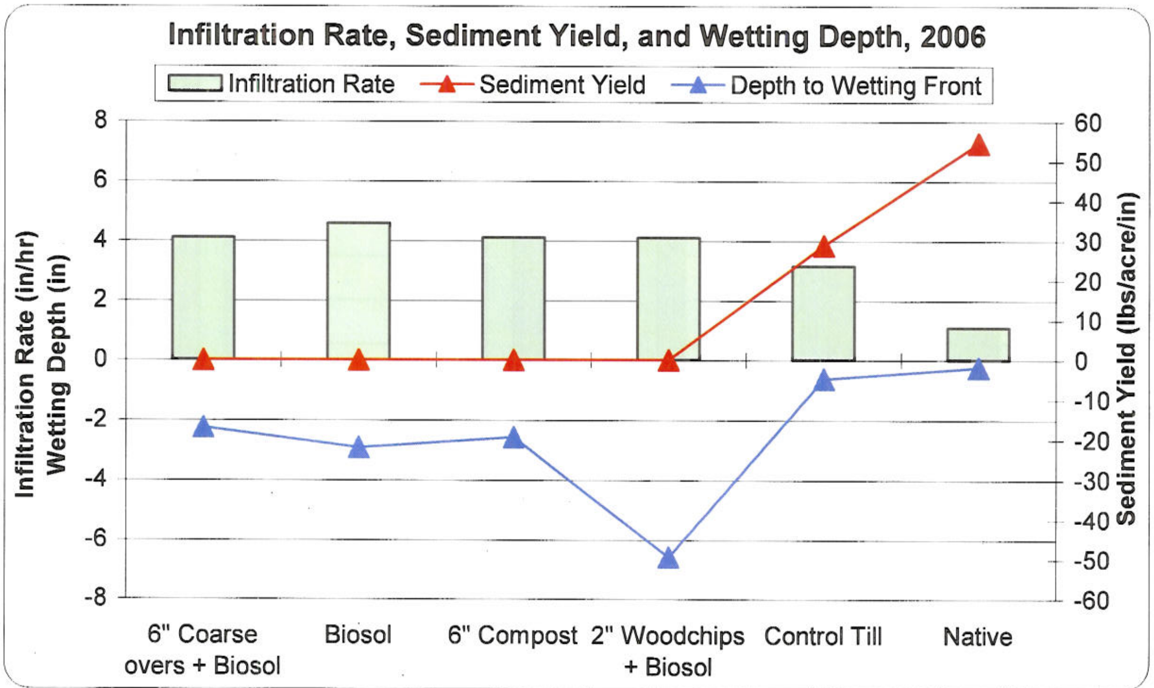

Figure 23. Infiltration Rate, Sediment Yield, Wetting Depth, 2006. The native plot and the control till plots had the highest sediment yields, the lowest infiltration rates, and the shallowest wetting depths and penetrometer DTRs.

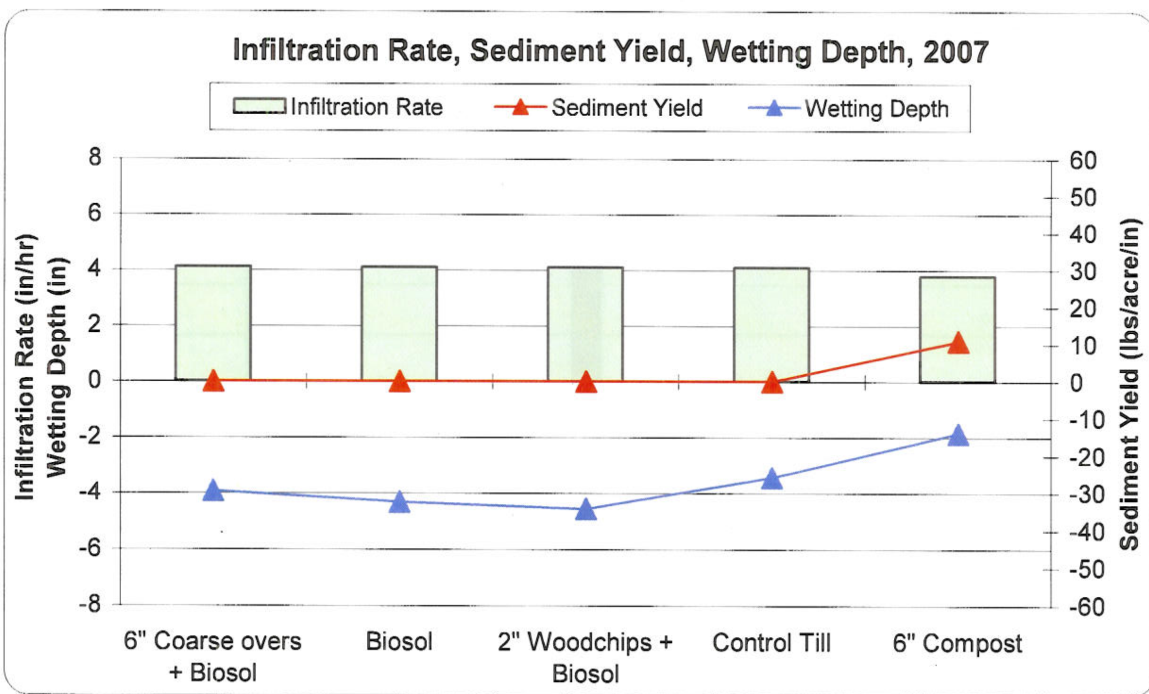

Figure 24. Infiltration Rate, Sediment Yield, Wetting Depth, 2007. The plots amended with 6 compost had the shallowest wetting depth and the highest sediment yield.

Wetting Depth

Wetting depths are measured following rainfall simulation and indicate the depth to which the water has penetrated the soil column. Over two years, plots that produced the most sediment had wetting depths that were on average 2 times shallower than at plots that did not produce sediment. In 2006, the control till plots and native plots both produced sediment greater than 29 lbs/acre/in (13 kg/ha/cm) and had wetting depths under 0.6 inches (1.5 cm). In 2007, the plot amended with six inches (15.2 cm) of compost produced 11 lbs/acre/in (4.8 kg/ha/cm) of sediment and had a depth to wetting of 1.9 inches (4.8 cm). All other plots in 2007 infiltrated 100% of rainfall, produced no sediment, and had wetting depths from 3.4 to 4.6 inches (8.6 cm to 12 cm).

The shallow wetting depth, 0.25 inches (0.6 cm), observed at the native area most likely resulted from the lateral movement of the applied rainfall water through the thick mulch layer. The water may have moved through the mulch layer and directly to the collection trough, with very little water reaching the soil.

Cover

Mulch Cover

In 2007, the fourth growing season, mulch cover remained greater than 80% on all treated plots (Figure 26). In 2006, mulch cover assessed by average ocular estimation ranged from 50% to 80% for each plot (Figure 25). This wide range in mulch cover is most likely a result of the assessment method as there is a high degree of inaccuracy with ocular estimation. The average depth of litter, measured only in 2007, was approximately ½ an inch.

High mulch cover is often associated with sediment reduction.[5] Other test plot areas (Truckee Bypass and Brockway test plots) did show a relationship between sediment yield and mulch cover in the first year after installation. A relationship between mulch cover and sediment reduction was not observed at the Heavenly test plots in 2006 or 2007, the third and fourth years after installation.

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[5] Grismer, ME, Hogan, MP. 2004. Evaluation of revegetation/mulch erosion control using simulated rainfall in the Lake Tahoe basin: 1. Method Assessment. *Land Degrad. & Develop.* 13:573-578.

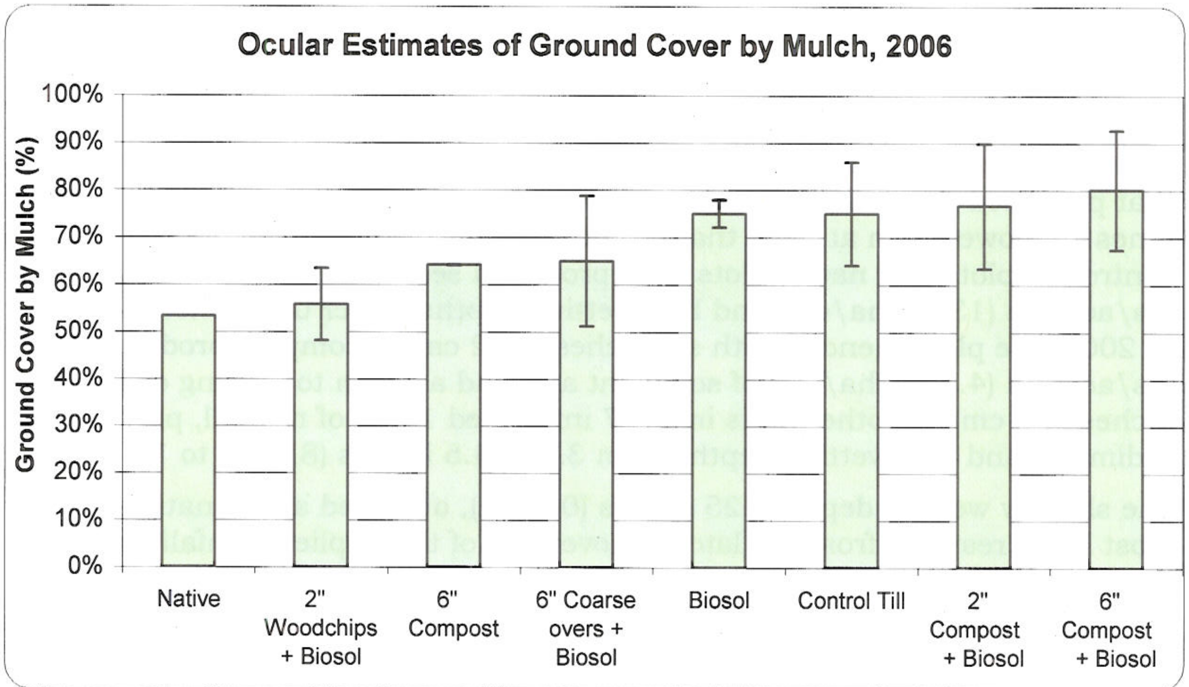

Figure 25. Ocular Estimates of Ground Cover by Mulch, 2006. In 2006, mulch cover ranged from 50% to 80%. In 2007, mulch cover was greater than 80%. Error bars denote one standard deviation above and below the mean.

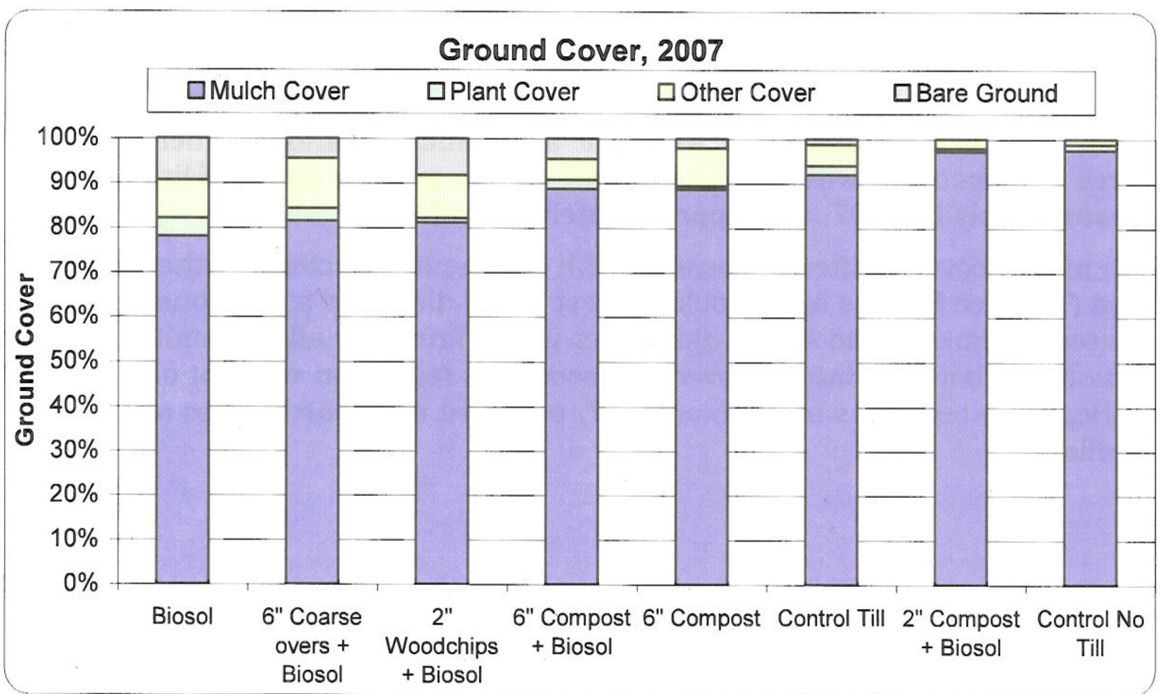

Figure 26. Ground Cover, 2007. Mulch ranged from 81% to 96% in 2007. Plots with higher sediment yield did not necessarily have lower mulch cover.

Plant Cover

In 2007, tilled plots with Biosol had almost two times higher average plant cover than plots without Biosol, as determined by the Mann-Whitney statistical test $U_{(6,12)} = 57.5$, $p < 0.05$ (Figure 27). The average plant cover for plots with Biosol added was 17.5%, while the average cover for plots without Biosol was 8.8%.

In 2006, the plots with coarse overs or compost had 1.4 times more plant cover than plots with woodchips or no amendment (Figure 27). The average cover for the plots with coarse overs or compost was 48%, while the average cover for the plots with woodchips was 34%, and cover for the plots without amendments was only 31%. In 2007, neither amendment type, addition of Biosol, nor tilling were correlated with total or perennial plant cover.

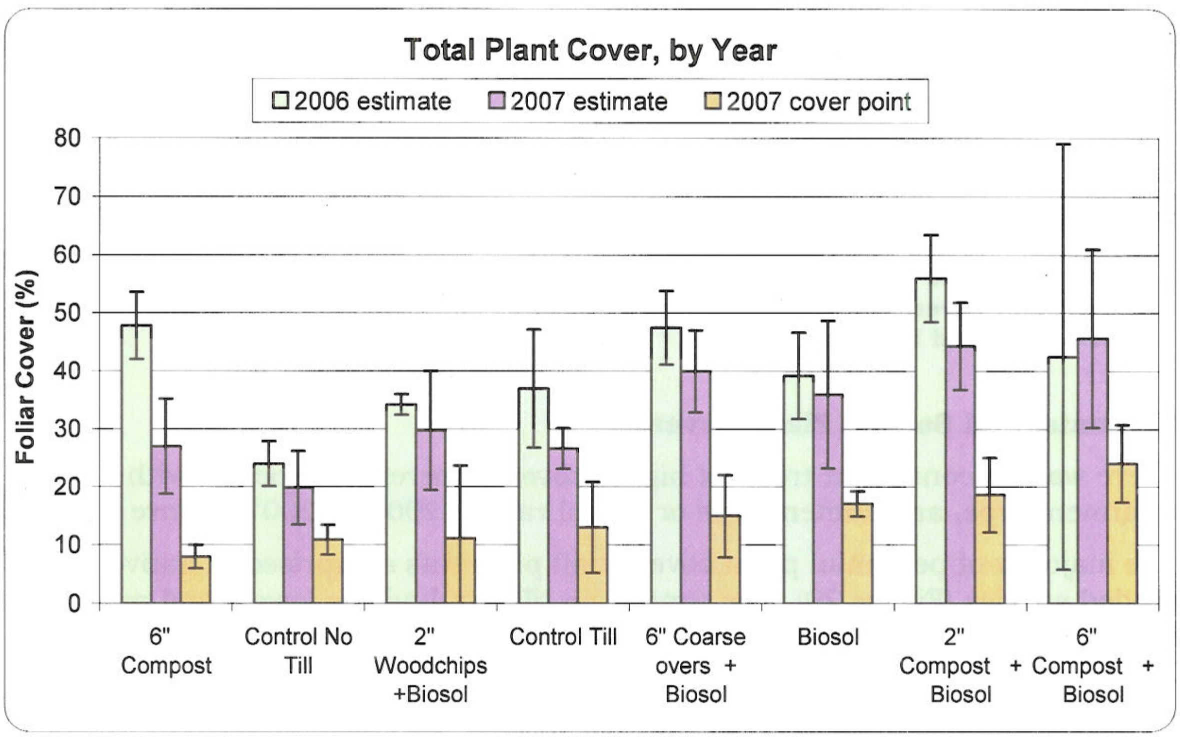

Figure 27. Total Plant Cover, 2006-2007. In 2006, plots with coarse overs or compost had 1.4 times higher plant cover than plots with woodchips or no amendment. In 2007, tilled plots with Biosol had almost two times higher average plant cover than plot without Biosol. The data is sorted by 2007 cover. Error bars denote one standard deviation above and below the mean.

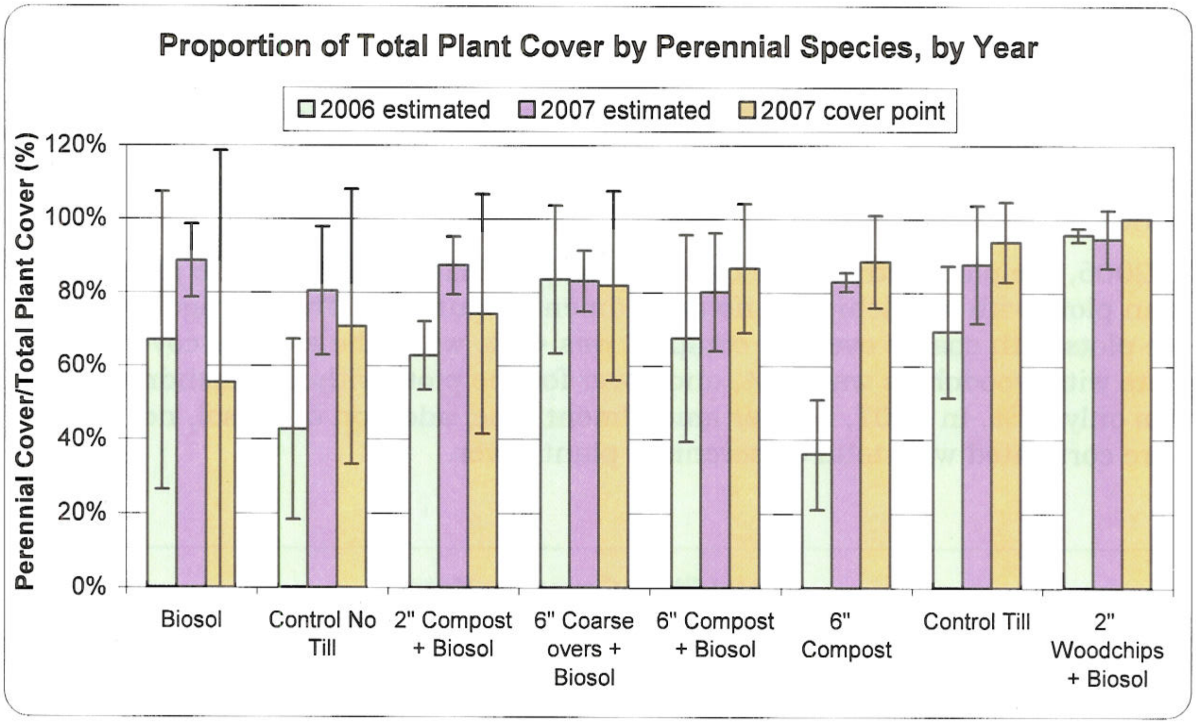

Figure 28. Proportion of Total Plant Cover by Perennial Species, by Year. In 2006, the plots with coarse overs and compost had higher plant cover than plots with woodchips. In 2007, no clear trends were observed between amendment type, addition of Biosol or tilling and perennial plant cover. The graph is sorted by 2007 cover. Error bars denote one standard deviation above and below the mean.

Perennial and Seeded Plant Cover

There was no consistent trend of higher cover by perennial species with treatment type, amendment type or Biosol rate in 2006 or 2007 (Figure 28).

The majority of perennial plant cover at all plots was comprised of native, seeded species (Figure 29). The control no till plot had the lowest and most inconsistent cover by perennials and seeded species averaged over 2006 and 2007 (Figure 28 and Figure 29).

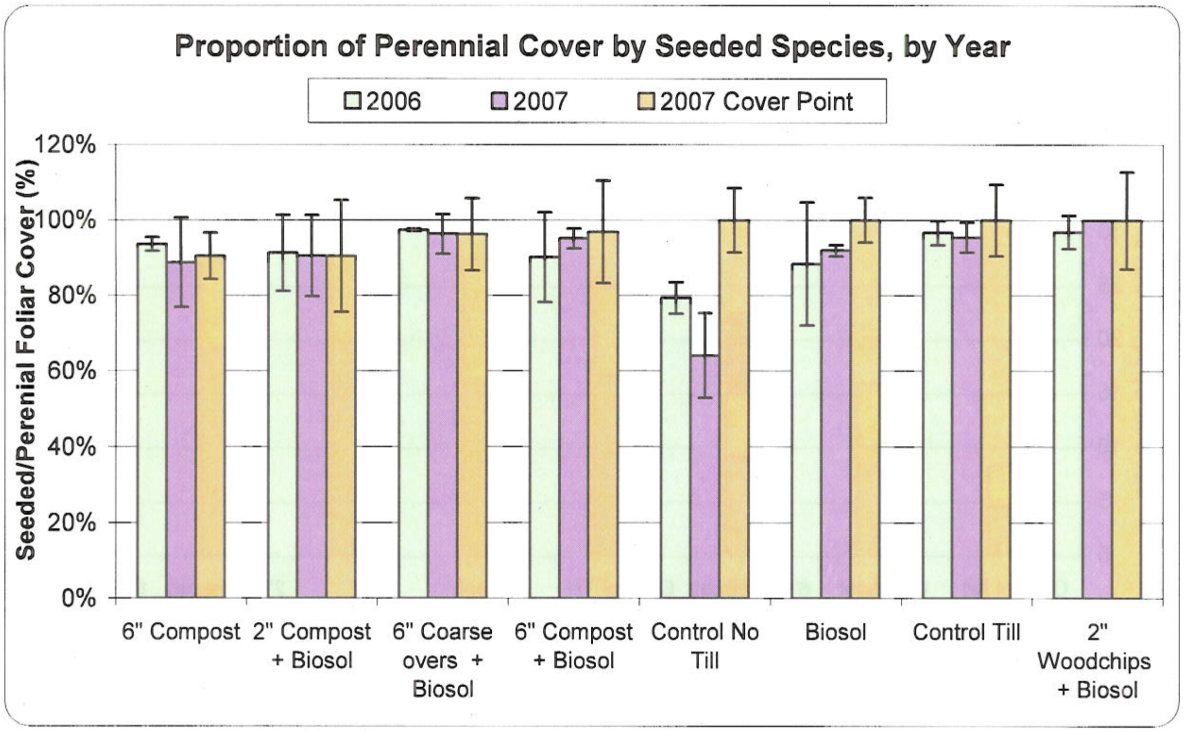

Figure 29. Proportion of Perennial Cover by Seeded Species, by Year. The majority of perennial species were comprised of native seeded perennial species. Error bars denote one standard deviation above and below the mean.

Species Composition

In both 2006 and 2007, Western needlegrass was the dominant seeded species at the treatment plots (Figure 30 and Figure 31). Western needlegrass represented 39 to 100% of the seeded species in 2006 and 2007, with an average cover of 69%.

At treated plots, Western needlegrass composed 1.4 times more of the plant cover by seeded species in 2007 than in 2006 (Figure 30 and Figure 31). The average proportion of Western needlegrass of seeded species at the treated plots was 57% in 2006 and 81% in 2007. Western needlegrass was also observed more often and at higher cover rates at other test plots sites in 2007, a low precipitation year.

In 2007, there was 24 times less cover by mountain brome versus in 2006 (Figure 30 and Figure 31). The cover by mountain brome of total seeded species cover was 9.6% in 2006, compared to 0.4% in 2007. This was observed at many other Caltrans test plots, indicating that this species may not do well during low precipitation years.

Blue wild rye was not observed in any of the plots in either year.

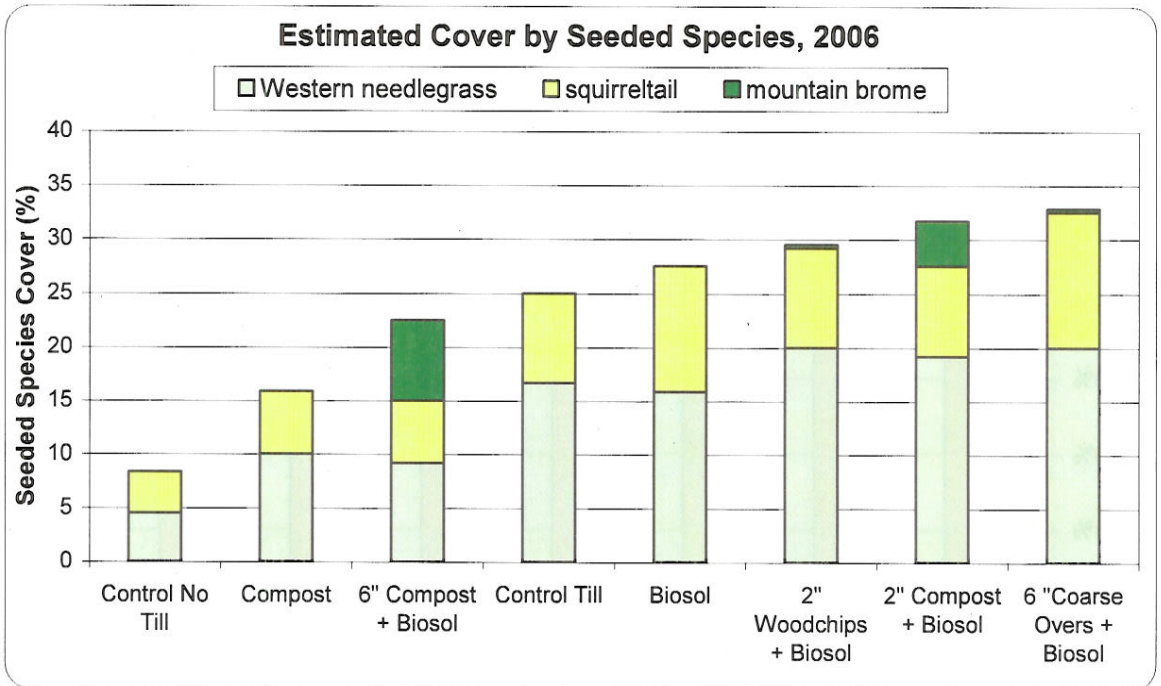

Figure 30. Estimated Cover by Seeded Species, 2006. Western needlegrass composed over 50% of cover on most plots.

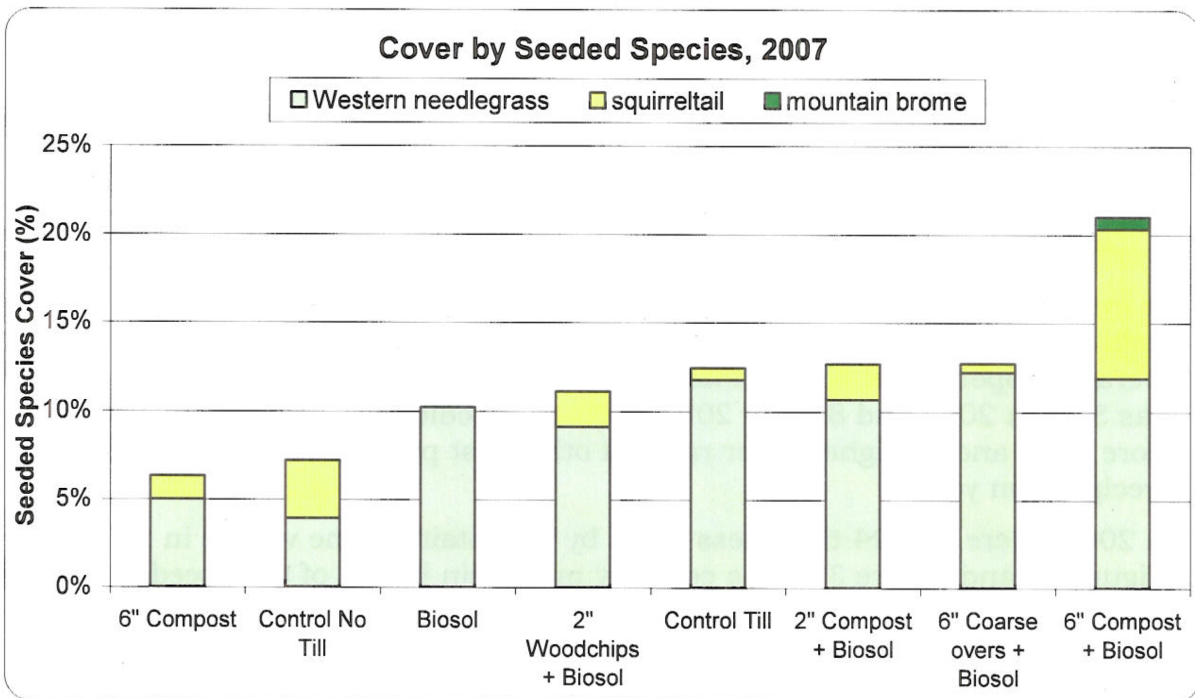

Figure 31. Cover by Seeded Species, 2007. Western needlegrass composed over 50% of cover at all plots, regardless of treatment.

Soil Physical Characteristics

Soil Density

Penetrometer depths were 3 times deeper post-treatment (2007) than pre-treatment (Figure 32 and Figure 33). In 2003, before treatment, the average penetrometer depth to refusal (DTR) at 250 psi was 5 inches, while in 2006 and 2007 the average DTR was 13 inches at the plots that received tilling treatments.

Tilled plots had penetrometer DTRs that were 6 to 11 times deeper than those at the untilled plots. From 2006 to 2007, the penetrometer depths ranged from 9 to 16 inches with slight variations between years and plots (Figure 33). The average penetrometer depth in 2006 and 2007 for tilled plots was 15 inches, while the average depth at the untilled plots was 1.4 inches.

In 2007, the penetrometer DTRs at the untilled plots were 10 times deeper than in 2005, indicating increasing soil density over time (Figure 33).

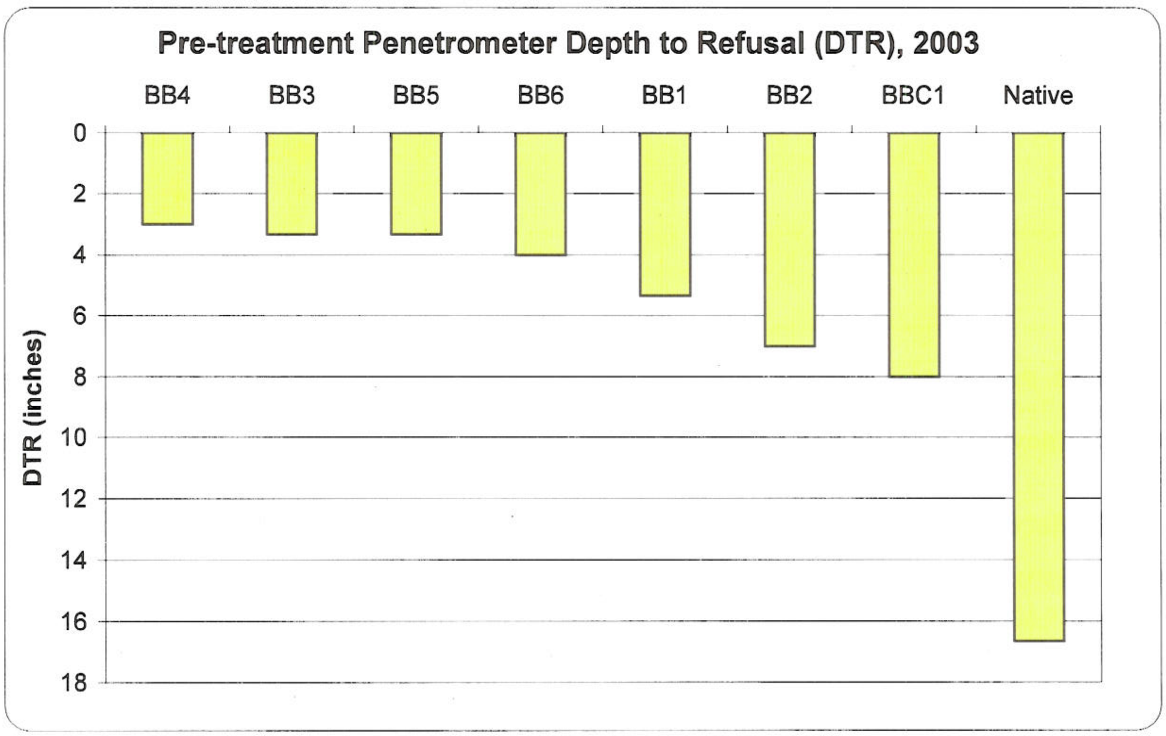

Figure 32. Pre-treatment Penetrometer Depth to Refusal (DTR), 2003. The native areas had much higher DTRs than the pre-treatment areas. The graph is sorted by increasing penetrometer DTR. Each bar represents a soil sample from a unique location in the treatment area, given a number or number and letter preceded by "BB".

In 2007, among tilled plots with different amendment type and rates, there was very little difference in penetrometer depths to refusal (Figure 33). However, post-rainfall penetrometer DTRs taken within the rainfall frames were 1.7 times deeper for plots with amendments than for the tilled plots without amendments (Figure 24). Post-rainfall DTRs were on average 15 inches for plots with amendments and only 9 inches for the control till plot.

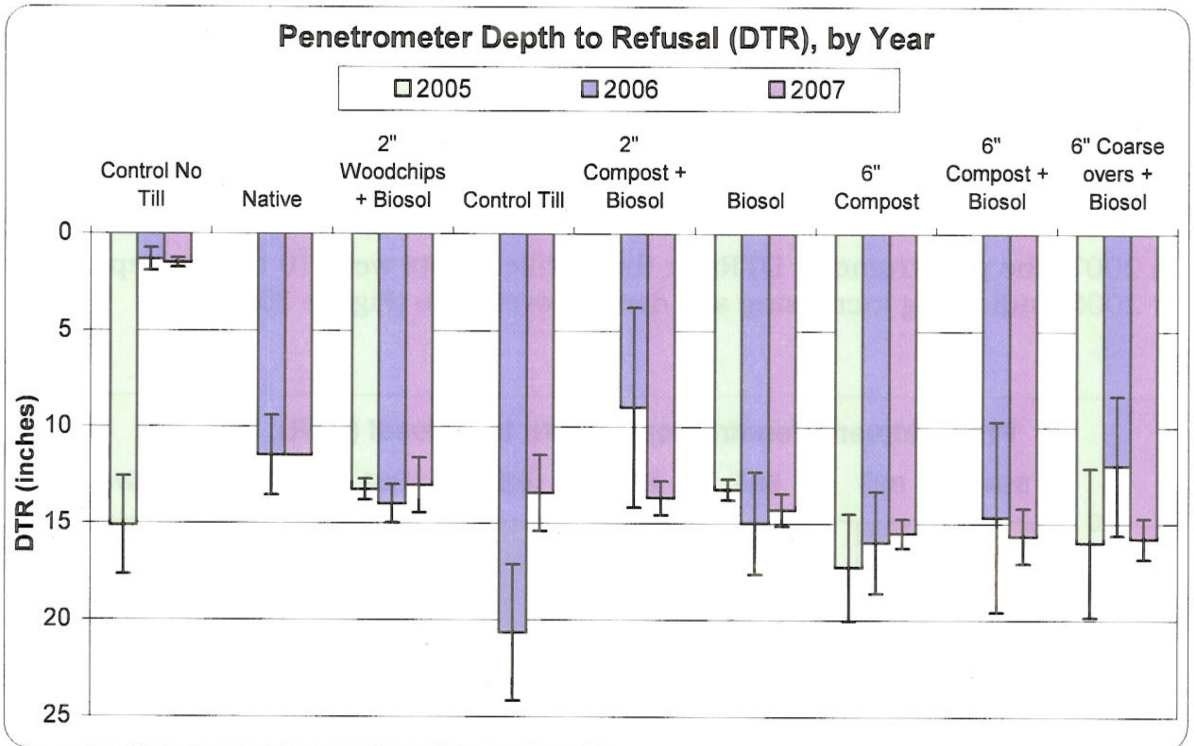

Figure 33. Penetrometer Depth to Refusal (DTR) by Year. Tilled plots have higher DTRs than untilled plots. Some treatments were not sampled in 2005. Error bars denote one standard deviation above and below the mean.

Soil Moisture

Soil moisture was measured at random points in 2005 and 2006 and on transects in 2007 during the height of the growing season. Soil moisture was similar for all years and all treatments. Only the 2006 and 2007 data are presented here because soil moisture in 2005 was not collected for all treatments (Figure 34). Soil moisture did not vary significantly by treatment type and was similar to native values. The range of soil moisture values was 4% to 6% over two years.

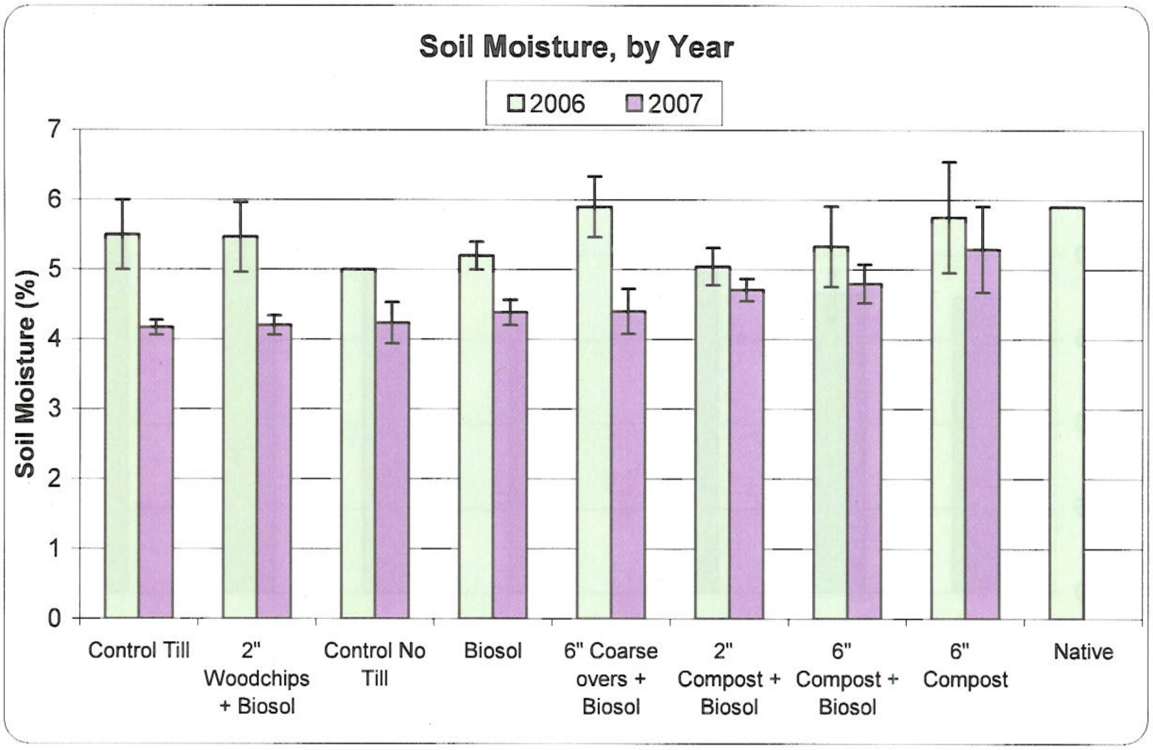

Figure 34. Soil Moisture by Year. Soil moisture was similar between years and treatments. Error bars denote one standard deviation above and below the mean.

Soil Strength

Soil shear strength was similar among all the treatment plots and similar to that recorded at a native site with granitic soil (Figure 35). The range of soil strength at the treatment plots was 17 to 25 kPa. A native site located on granitic soil along Highway 50 in South Lake Tahoe recorded a shear stress value of 22 kPa.

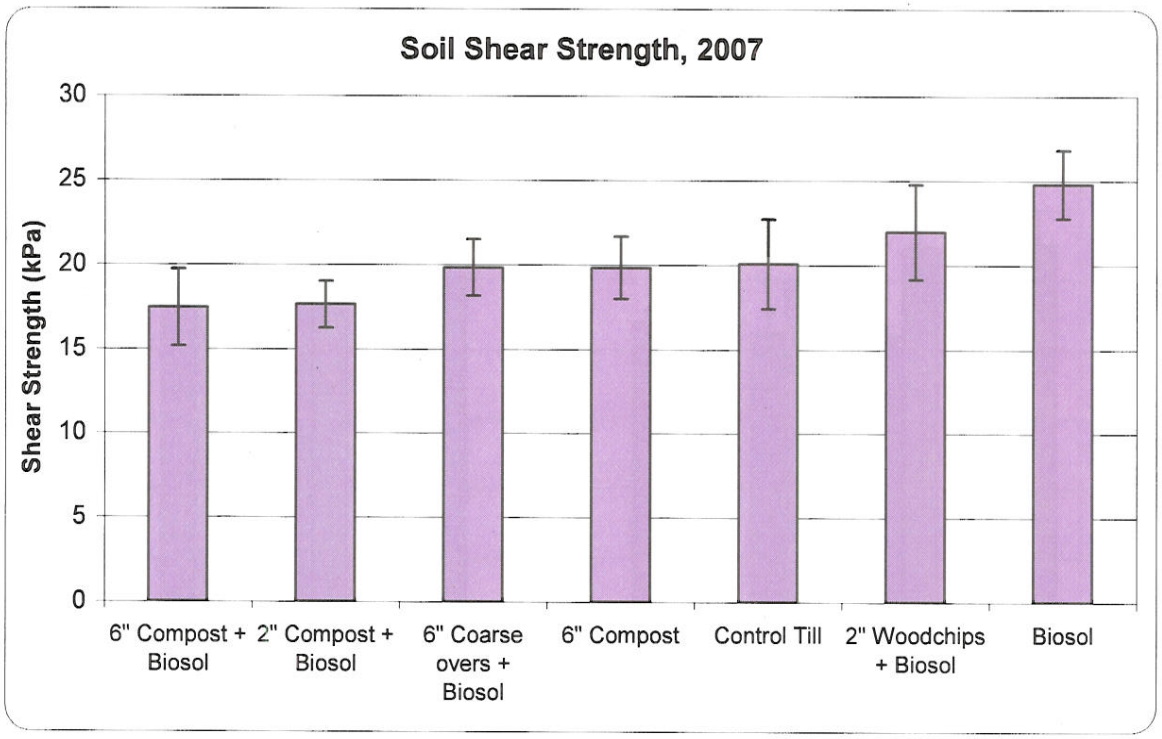

Figure 35. Soil Shear Strength, 2007. Soil Shear strength was similar among all treatment plots. Error bars represent one standard deviation above and below the mean.

Soil Nutrients

In 2006 and 2007, total Kjeldahl nitrogen levels at the treatment plots were double the pre-treatment levels (Figure 36 and Figure 37). Pre-treatment TKN levels were between 200 and 450 ppm in 2003. In 2006, the total Kjeldahl nitrogen (TKN) was between 700 and 1,400 ppm, depending on treatment type (Figure 37). In 2007, TKN levels were within a similar range, from 610 ppm to 1,328 ppm (Figure 37).

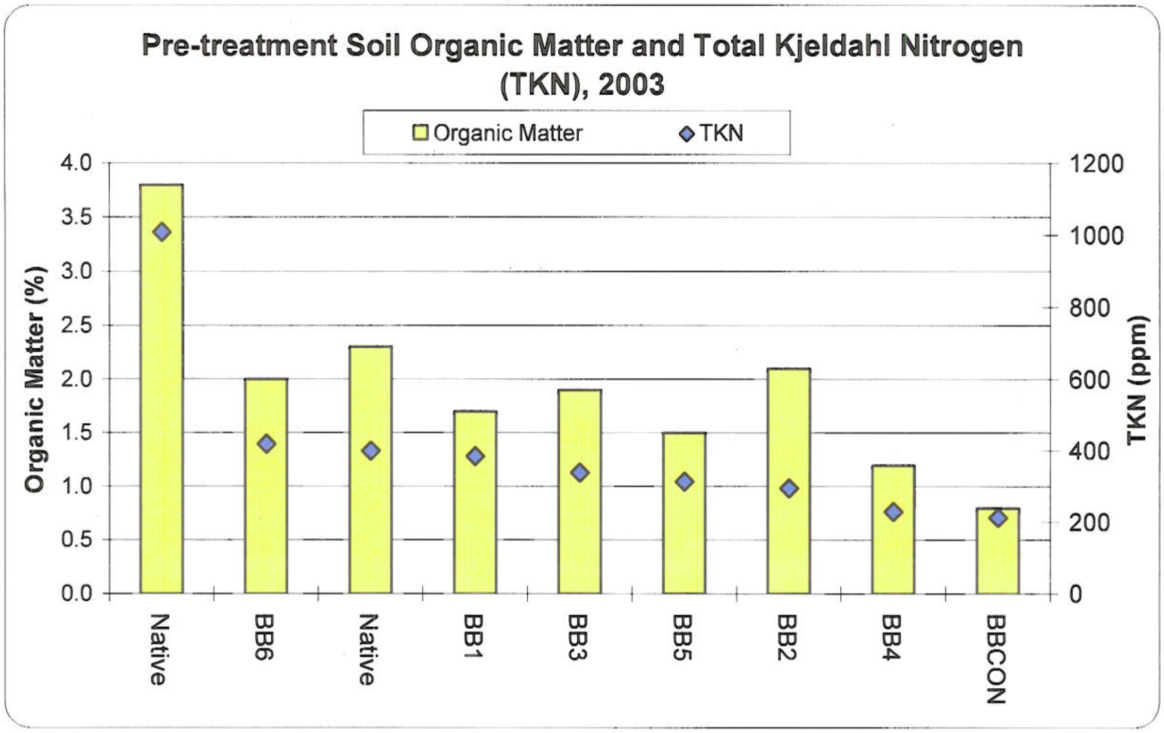

Figure 36. Pre-treatment Soil Organic Matter and Total Kjeldahl Nitrogen (TKN), 2003, On average, pre-treatment levels were half that of post-treatment levels. The graph is sorted by decreasing TKN. Each bar represents a soil sample from a unique location in the treatment area, given a number or a number and letter preceded by "BB".

In 2006 and 2007, the coarse overs and Biosol treatment had the highest TKN level (greater than 1,300 ppm) compared to the other treated plots that had TKN values that ranged from 610 to 1075 ppm and the native area that had a TKN of 1,028 ppm (Figure 36 and Figure 37). The organic matter content was also higher for the coarse overs and Biosol plot (greater than 3.8%) compared to 3.3% at the native site and between 1.6 and 3% for the other treatment sites. The compost and Biosol plots also had the second highest TKN level (1,075 ppm) which was similar to that of the native site (Figure 37). Of all the test plot treatments, the plot with 2 inches of woodchips and Biosol had the lowest TKN in 2007 (610 ppm). This was less than half the level of TKN recorded for the coarse overs and Biosol plot.

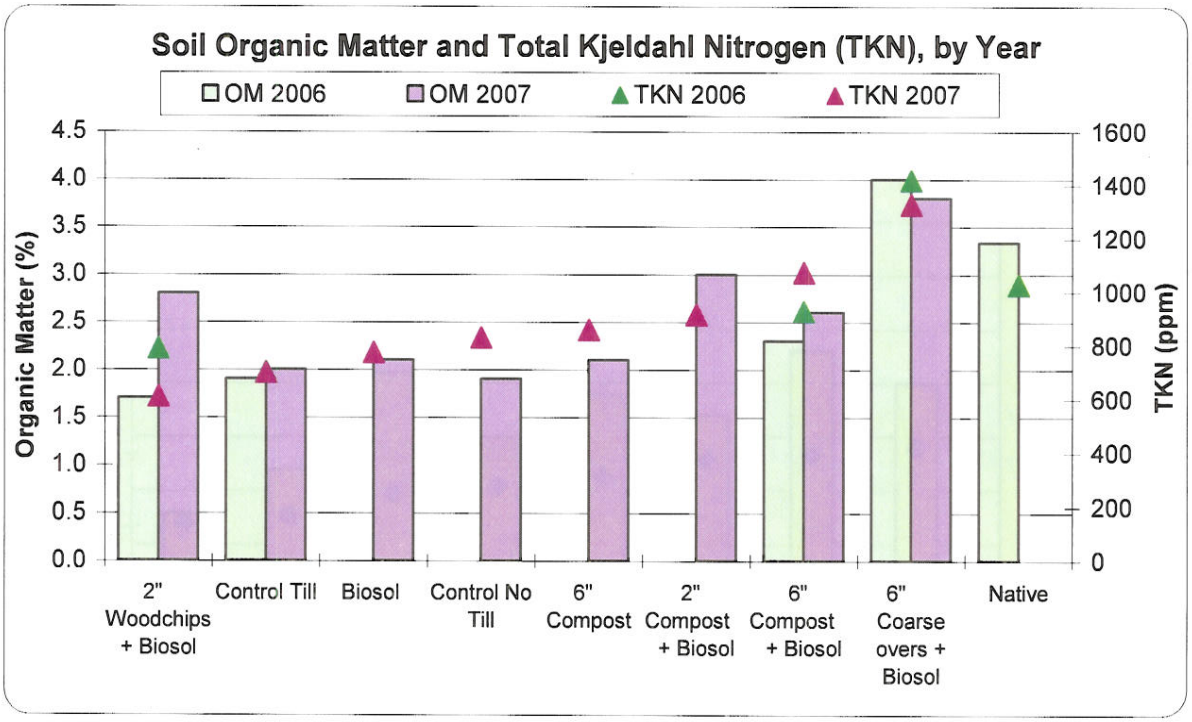

Figure 37. Soil Organic Matter and Total Kjeldahl Nitrogen (TKN), by Year. OM stands for organic matter.

Solar Radiation

The mean solar radiation during the peak of the summer growing season (June to August) at the Heavenly test plots is 85%. The range in solar radiation at the test plots is between 78 and 91%. This difference is not great and is due to the effect of the nearby forest on the edges of the test plots (Figure 2). The mean solar radiation at the native site is only 22.5% because this site is within the forest canopy (Figure 2). The difference in solar radiation among the test plots is most likely not great enough to affect the plant growth.

CONCLUSIONS

Infiltration

- All the treatment plots exhibited high infiltration rates and low sediment yields, which were similar to or greater than those at the native site (Figure 21 and Figure 22).
- Tilled plots with coarse organic amendments (woodchips or coarse overs), infiltrated 100% of the applied rainfall and produced no sediment in four years of rainfall simulations (Figure 21 and Figure 22).
- In 2006 and 2007, the control till plots, which had the greatest sediment yield, also infiltrated three times less applied rainfall water than treated plots (Figure 23 and Figure 24).
- Over two years, plots that produced the most sediment had wetting depths that were on average 2 times shallower than at plots that did not produce sediment.

Mulch Cover

- After 4 growing seasons, mulch cover remained greater than 80% for all treated plots (Figure 26).

Plant Cover

- In 2007, as determined by the Mann-Whitney statistical test ($U_{(6,12)} = 57.5$, $p < 0.05$), tilled plots with Biosol had almost two times higher average plant cover than plots without Biosol (Figure 27).
- In 2006, the plots with coarse overs or compost had at least 1.4 times more plant cover than plots with woodchips (Figure 27).
- In 2007, neither amendment type or rate, addition of Biosol, nor tilling were correlated with total or perennial plant cover (Figure 27 and Figure 28).

Plant Composition

- In both 2006 and 2007, plots with higher cover by perennial species had higher cover by seeded species (Figure 29 and Figure 31).
- The control no till plot had the lowest and most inconsistent cover by perennials and seeded species, as low as 40%, in both 2006 and 2007 (Figure 28 and Figure 29).

- Western needlegrass was the dominant seeded species in 2006 and 2007.
- At treated plots, Western needlegrass composed 1.4 times more of the plant cover by seeded species in 2007 than in 2006 (Figure 30 and Figure 31).
- In 2007, there was 24 times less cover by mountain brome than in 2006 (Figure 30 and Figure 31).
- Blue wild rye was not observed in any of the plots in either year.

Soil Density

- Penetrometer depths were 3 times deeper post-treatment (2007) than pre-treatment (Figure 32 and Figure 33).
- Tilled plots had penetrometer DTRs that were 6 to 11 times deeper than those at the untilled plots (Figure 33).
- In 2007, the penetrometer DTRs at the untilled plots were 10 times shallower than in 2005, indicating increasing soil density over time (Figure 33).
- In 2007, among tilled plots with different amendment types and rates, there was very little difference in penetrometer depths to refusal (Figure 33).

Soil Moisture

- Soil moisture was similar for all years and all treatments.

Soil Strength

- Soil shear strength was similar among all the treatment plots and similar to that recorded at a native site in granitic soil (Figure 35).

Soil Nutrients

- In 2006 and 2007, total Kjeldahl nitrogen levels at the treatment plots were double the pre-treatment levels (Figure 36 and Figure 37).
- In 2006 and 2007, the coarse overs and Biosol treatment had the highest TKN level (greater than 1,300 ppm), compared to the other treated plots that had a TKN range of 610 to 1075 ppm and the native area that had a TKN of 1,028 ppm (Figure 36 and Figure 37).

- The organic matter content was highest for the coarse overs and Biosol plots (greater than 3.8%) compared to 3.3% at the native site and between 1.6 and 3% for the other treatment sites.
- The compost and Biosol plots had the second highest TKN level 1,075 ppm, which was similar to that of the native site (Figure 37).

Solar Radiation

- The difference in solar radiation among the test plots, 78 to 91%, is most likely not great enough to affect the plant growth.

RECOMMENDATIONS

These recommendations are for a site with approximately 85% solar exposure, on a 16 degree slope, at an approximate elevation of 8,500 ft (2,618 m), with granitic parent material soil and no seed source of invasive annual plants.

Tilling: 12 inches (30 cm) incorporating 6 of coarse overs

Biosol: 1,780 lbs/acre (2,000 kg/ha) of Biosol

Seed: 125 lbs/acre (140 kg/ha) of native seed with the following composition:

Western needlegrass: 60%
squirreltail: 25%
mountain brome: 15%

Mulch: 2 inches of pine needles

Soil loosening versus No soil loosening

Tilling to 12 inches (30 cm) is recommended for the following reasons. Tilled plots exhibited:

- up to 2 times more perennial plant cover and cover by seeded species than untilled plots
- penetrometer DTRs 6 to 11 times deeper than at untilled plots

Amendments (coarse overs, woodchips, compost) versus No Amendments

It is recommended that the soil be amended and tilled deeply with organic material for the following reasons. Most plots amended with coarse overs, woodchips, or compost exhibited:

- a similar percent organic matter to that at native sites.
- a similar TKN to native sites

Amendment Type and Rate (Coarse overs, Woodchips, or Compost)

Coarse overs spread to a depth of 6 inches are recommended for the following reasons. Plots with 6 inches of coarse overs exhibited:

- TKN that was between 1.2 to 2.1 times higher than at plots with woodchips or compost in 2006 and 2007, and higher than native levels
- organic matter that was 1.3 to 2 times that of plots with woodchips or compost in 2006 and 2007
- 100% infiltration of applied rainfall simulation water for all 4 sampling years, which was similar to the woodchip amended plot, 8% higher than the compost amended plots, and 12% higher than the control till plot
- no sediment production for all 4 sampling years, which was similar to the plots amended with 2 inches of woodchips (all other treated plots and the native plot produced slightly higher sediment yields in at least one or more of the sampling years)
- similar penetrometer DTRs to the plots amended with compost or woodchips

Biosol versus No Biosol

Biosol application at 1,780 lbs/acre (2,000 kg/ha) in combination with an organic amendment is recommended for the following reasons. Plots with Biosol exhibited:

- nearly twice as much plant cover than plots without Biosol
- TKN that was 1.1 to 1.5 times higher than other treatment plots when combined with either compost or coarse overs
- organic matter that was 1.2 to 1.8 times higher than other treatment plots when combined with either compost or coarse covers

Seed

Native seed is recommended at the tested rate of 125 lbs/acre (140 kg/ha). Suggested species composition is:

Western needlegrass: 60%
squirreltail: 25%
mountain brome: 15%

The tested composition included approximately 30% mountain brome, 25% squirreltail, 25% blue wild rye, and 13% Western needlegrass. The recommended composition is different from the applied composition for the following reasons:

- Western needlegrass was the dominant species in 2006 and 2007, composing 39 - 100% of cover by seeded species; therefore, it is recommended to dominate the seed mix.
- Cover by mountain brome decreased by 24 times between 2006 and 2007, therefore, its proportion in the seed mix was decreased.
- Blue wild rye was not observed in 2006 or 2007, therefore it was removed from the recommended mix.

Mulch

Mulch is recommended at the only tested depth of 2 inches (5 cm) for the following reasons:

- mulch cover was maintained at greater than 80% cover

Appendix A

2006 Species List for the Heavenly test plots.

								Ocular Estimate (%)																												
Lifeform	Family	Scientific name	Common name	Annual/ Perennial	Native/ Alien	Noxious/ Invasive	Phenology	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	west of 27	Native
Forb	Asteraceae	Achillea millefolium	yarrow	Perennial	Native		Veg.											T									T				T					
Forb	Brassicaceae	Arabis platysperma	pioneer rockcress	Perennial	Native		Seed					T						5										T							T	T
Forb	Polemoniaceae	Collomia tinctoria	tinted collomia	Annual	Native		Flower																		T											
Forb	Polygonaceae	Eriogonum nudum	nude buckwheat	Perennial	Native		Veg.					T							T																T	
Forb	Polygonaceae	Eriogonum spergulinum	spurry buckwheat	Annual	Native		Flower							20	< 5				T	T		T				5	5 - 10		T	T	T	10	5 - 10	T	T	
Forb	Brassicaceae	Erysimum capitatum	Western wallflower	Perennial	Native		Flower												T										T							
Forb	Onagraceae	Gayophytum diffusum	prarie smoke	Perennial	Native		Flower	30	40	T	35	T	< 5	20	5 - 10	T		10		20	20	20	5 - 10		T	5	5 - 10		10	10	30	10	5 - 10	15	15	
Forb	Onagraceae	Oenethera sp.	evening primerose	Perennial	Native		Veg.	T																												
Forb	Scrophulariaceae	Penstemon newberryi	pride of the mountain	Perennial	Native		Flower			T																		T	T							
Forb	Scrophulariaceae	Penstemon sp.	penstemon	Perennial	Native		Flower																							T				T	T	
Forb	Hydrophyllaceae	Phacelia hastata	silverleaf phacelia	Perennial	Native		Veg.							T						T		T				T										
Forb	Scrophulariaceae	Verbascum thapsis	mullen	Annual	Native	Invasive	Flower		T					T				< 5																		
Graminoid	Poaceae	Achnatherum occidentalis	Western needlegrass	Perennial	Native		Seed	20	20	20	15	15	25 - 35	5	< 5	25 - 35		15 - 25	5 - 10	5	< 5	15 - 20	15		20 - 25	5 - 10	20		20 - 25		5 - 10	15	5 - 10	25	5	
Graminoid	Poaceae	Agropyron intermedium	intermediate wheatgrass	Perennial	Alien		Seed				T							T		T								T							5	
Graminoid	Poaceae	Bromus carinatus	mountain brome	Perennial	Native		seed	10 - 15	20 - 25	T															T					T					T	
Graminoid	Cyperaceae	Carex rossii	Ross' sedge	Perennial	Native		Veg.								T						T															15
Graminoid	Cyperaceae	Carex sp.	sedge	Perennial	Native		Flower																									T	T			
Graminoid	Poaceae	Dactyls glomerata	orchard grass	Perennial	Alien	Invasive	Veg.													T																
Graminoid	Poaceae	Deschampsia elongata	elongated hairgrass	Perennial	Native		Seed																													
Graminoid	Poaceae	Elymus elymoides	squirrel's tail grass	Perennial	Native		Flower			20	5 - 10	15	5 - 10	5 - 10	< 5	15		10	5 - 10	5	T	5	10		10	5 - 10	15	10	5 - 10		5	10	5 - 10	10	T - 5	
Graminoid	Poaceae	Elymus glaucus	blue wildrye	Perennial	Native		Seed																													
Graminoid	Poaceae	Festuca	Fescue	Perennial	Native		Veg.								T				T											T					T	
Graminoid	Poaceae	Poa wheeleri	Wheeler's bluegrass	Perennial	Native		Seed																													
Graminoid	Poaceae	Tritesum spicatum	spike trisetum	Perennial	Native		Seed																													10
Shrub	Grossulariaceae	Ribes cereum	wax leaf currant	Perennial	Native		Veg.																												T	
Tree	Pinaceae	Pinus contorta	lodgepole pine	Perennial	Native		Veg.						T		T	T		T	5 - 10		T						5			T					5	
Tree	Pinaceae	Pinus monticola	Western white pine	Perennial	Native		Seedling																													T

2007 Species List for the Heavenly test plots.

Lifeform	Family	Scientific name	Common name	Annual/ Perennial	Native/ Alien	Noxious/ Invasive	% in seed mix	Ocular Estimate (%)																											
								Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Plot 11	Plot 12	Plot 13	Plot 14	Plot 15	Plot 16	Plot 17	Plot 18	Plot 19	Plot 20	Plot 21	Plot 22	Plot 23	Plot 24	Plot 25	Plot 26	Plot 27	Native
Forb	Asteraceae	Achillea millefolium	yarrow	Perennial	Native													T										T			T				
Forb	Brassicaceae	Arabis platysperma	pioneer rockcress	Perennial	Native																														T
Forb	Polemoniaceae	Collomia tinctoria	tinted collomia	Annual	Native																														
Forb	Polygonaceae	Eriogonum nudum	nude buckwheat	Perennial	Native																														
Forb	Polygonaceae	Eriogonum spergulinum	spurry buckwheat	Annual	Native			5	T	<5	T	T	T	5	<5	<5	T	T	T	5	<5	<5	T	<5		5-10	10	5	T	T	T	T	10	<5	
Forb	Brassicaceae	Erysimum capitatum	Western wallflower	Perennial	Native												T	10-15	T		T	T						5-10	T					T	
Forb	Onagraceae	Gayophytum diffusum	prairie smoke	Perennial	Native			T	T	T	T	T	T	T	T	T	T	T		T	T	T				T	T	T		T	<5	T	T	<5	
Forb	Onagraceae	Oenothera sp.	evening primerose	Perennial	Native																														
Forb	Scrophulariaceae	Penstemon gracilentus	penstemon	Perennial	Native																									T			T	T	
Forb	Scrophulariaceae	Penstemon newberryi	pride of the mountain	Perennial	Native					T																		T	T		T				
Forb	Hydrophyllaceae	Phacelia hastata	silverleaf phacelia	Perennial	Native									T			T			T		T		T											
Forb	Scrophulariaceae	Verbascum thapsis	mullen	Annual	Native	Invasive								T				T																	
Graminoid	Poaceae	Achnatherum occidentale	Western needlegrass	Perennial	Native		12.6%	25	40	20	10	15-20	25-30	20	5-10	25-35	T	15-25	10	15	<5	15	15-20	T	25-35	5	25-30	30	25	T	10	20	5	20	
Graminoid	Poaceae	Agropyron intermedium /Elytrigia intermedia ssp. intermedia	intermediate wheatgrass	Perennial	Alien														T	T															
Graminoid	Poaceae	Bromus carinatus	mountain brome	Perennial	Native		29.0%	T	T	T	T						T													T					
Graminoid	Cyperaceae	Carex multicostata	sedge	Perennial	Native																											T	T		
Graminoid	Cyperaceae	Carex rossii	Ross' sedge	Perennial	Native										T						T														15
Graminoid	Poaceae	Dactylis glomerata	orchard grass	Perennial	Alien	Invasive																													
Graminoid	Poaceae	Deschampsia elongata	elongated hairgrass	Perennial	Native																														
Graminoid	Poaceae	Elymus elymoides	squirrel's tail grass	Perennial	Native		26.5%	10	10-15	20	5-10	<5	T	10	<5	5-15	T	10	5	5	<5	<5	5		5-10	10	10-15	10	5		<5	5	10-15	5	
Graminoid	Poaceae	Elymus glaucus	blue wildrye	Perennial	Native		24.5%																												
Graminoid	Poaceae	Festuca trachyphylla	hard fescue	Perennial	Native														T		T			T					T	T					
Graminoid	Poaceae	Poa wheeleri	Wheeler's bluegrass	Perennial	Native																														
Graminoid	Poaceae	Trisetum spicatum	spike trisetum	Perennial	Native																														10
Shrub	Ericaceae	Arctostaphylos nevadensis	pinemat manzanita	Perennial	Native																														
Shrub	Grossulariaceae	Ribes cereum	wax leaf currant	Perennial	Native																														
Tree	Pinaceae	Pinus contorta	lodgepole pine	Perennial	Native												T													T					
Tree	Pinaceae	Pinus monticola	Western white pine	Perennial	Native								T	T	T	T	T	T	10		T				T		T			T	T				T